Environmental pressure reduction with a new method of noble metal recovery

EV Filippova
Transbaikal State University, Chita, Russia
E-mail: filena78@mail.ru

Abstract. Discoveries in the area of hydrometallurgy of noble metals can be of use in metal recovery from low-grade solutions and slurries, including liquid tailings. Efficiency of noble metal recovery and reduction in mining waste is gained owing to utilization of two forms of ion-exchange sorbent, including \( \text{OH}^- \) for recovery of cyanic compounds of gold and cyanides, which allows abating burden on natural systems.

Easy gold reserves have almost been depleted so far. Major gold reserves are now composed of very fine particles. Moreover, concentration of gold in ore is low. None of the known beneficiation circuits provide complete recovery of such gold, and some gold is lost in tailings in the form of overground aggregates with gangue. The average gold content of ore is 0.001% (10 g/t), and tailings contain 99.9% of extracted rocks. By 2015 Transbaikalia has accumulated 2.9 Bt of waste in dumps and tailings of flotation and gravity concentration [1]. Industrial waste dramatically impairs the environment, including hydrosphere, pedosphere, flora and fauna. Waste substances, including toxic, spread from tailing ponds with water or when dams are destroyed. In drained areas or from concentrate storage yards, toxic matters go with wind and also invite danger.

For the ecological relaxation and in order to enhance recovery of gold and associate chemical elements that are most often pollutants, new approaches and technologies should be developed considering the environmental safety. In this respect, the research has been undertaken to analyze feasibility of development of an efficient and integrated technology for minimization of mining and processing waste and to regenerate eco-systems in the areas of operating mines and processing plants with regard to their specificity.

The scope of the research embraced theories and generalizations, multi-factor experimentation planning, mathematical processing of the experimental results, granulometric, mineralogical, spectral, chemical, X-ray phase, optical, electron microscopic, microscopic, bacterioscopic, atomic absorption, assaying, X-ray structural and another analyses, process testing, desk studies as well as large-scale laboratory and semi-industrial trial of additional leaching of gold with preparation of feedstock in solutions and pulp slurry.

In the course of the research implementation, the process of noble metal recovery has been improved [2] under the guidance of Dr Eng Sekisov, which enhanced efficiency of recovery of gold, chemical combined elements and activated leaching solutions due to the re-designed electro-absorption plant, specific flow of pulp slurry, two new species of an ion-exchange sorbent and increased activity of adsorption and deposition of noble metals on cathodes.

A distinctive feature of the new method to extract noble metals from pulp slurry is additional milling of mineral particles of pulp slurry to unlock dispersed gold particles before feeding the pulp.
slurry in the electro-absorption plant. The ion-exchange sorbent is fed in the plant first as CN\(^-\), for additional leaching of dispersed gold at early stages of recovery, and then as OH\(^-\), to extract cyanides and cyanide–gold complexes at later stages of the circuit. This allows mitigation of anthropogenic load on the nature and produces the beneficial ecological effect.

Figure 1 shows the layout (vertical) and A-A cross section of the electro-absorber designed for small-scale industry.

![Figure 1. Electro-absorber for the small-scale industry: 1—body composed of five units (external cylinder); 2—inlet pipe; 3—outlet pipe; 4—internal perforated cylinder; 5—cathode; 6—anode; 7—bypass pipe; 8—discharge pipe (to tailings pond); 9—bypass hole.](image)

The body 1 of the electro-absorber contains a number of units with inlet pipes 2 to let in pulp slurry from the pulp slurry pipeline and outlet pipe 3 to let out pregnant ion-exchange sorbent. Inlet pipe 2 is arranged at an angle relative to the inner surface of the external cylinder of the body. The body 1 of each section is composed of two cylinders (external and internal) that are rigidly coupled; the radius of the internal cylinder makes 0.23–0.25 of the radius of the external cylinder. The internal cylinder 4 has perforation. The size of the perforation holes is chosen based on the condition of separation of the ion-exchange sorbent with gold anions and the pulp slurry fluid and its free outflow.

In the external cylinder 1, electrodes 5 and 6 are installed one behind the other along the pulp slurry flow, which reduces abrasive effect on the protective corrosion-resistant surface of the anodes. The difference of the potentials between the anodes and cathodes is conditioned by the physicochemical parameters of pulp slurry and by the content of ion-exchanger in it, and should be sufficient to ensure high-rate electrochemical processes in the electro-absorber.

From hole 9 in the bottom of each unit of the internal perforated cylinder, the bypass pipe 7 goes to the lower lying unit of the external cylinder of the electro-absorber. The bypass pipe is curved to amplify centrifugal force and to direct the pulp slurry flow to the next unit of the plant.

Separation of the pregnant ion-exchange sorbent and discharge of the pulp slurry from a unit takes place in the internal perforated cylinder 4. The pulp slurry to be discharged to a tailings pond is let out via the discharge pipe 8.

Granules of the ion-exchange sorbent are placed in the electro-absorber before the pulp slurry is fed there. In our case, the gold-selective sorbent of grade A-100 was used in amount of 10% of the volume.

Pulp slurry flows comes from the pulp slurry pipelines, through vortex generators installed in the expanded part of the pipeline in front of the inlet pipe for additional grinding of mineral particles containing fine gold.

Then, the flow goes in the external cylinder 1 of the electro-absorber though the inlet pipe 2 where mineral particles collide and bump against the cathodes. The prepared ion-exchange sorbent in the
form of CN⁻ mixes with the pulp slurry, interacts with mineral particles, leaches unlocked gold fines and is saturated with them. At the later stage of this circuit, the pulp slurry interacts with the ion-exchange sorbent in the form of OH⁻, and additional recovery of cyanides and gold-and-cyanide complexes takes place. This reduces the load on the nature as migration and hypergenesis of cyanides in tailings ponds is eliminated.

The ion-exchange sorbent granules and the pulp slurry are separated when the pulp slurry flows through the perforated holes of the internal cylinder 4. The pulp slurry, after electroactivation and electro-deposition in the first unit, freely flows through the perforation holes of the internal cylinder 4 from the first unit to the second unit, then via the bypass pipe 7—to the external cylinder of each lower-lying unit and, finally, is let out from the electro-absorber by the discharge pipe 8. The ion-exchange sorbent granules, owing to the centrifugal force, circulate in the electro-absorber space between the internal and external cylinders and remain there until complete saturation. The pulp flow rate in a unit ensures the pre-set recovery efficiency.

In the zone between the cathodes and anodes, partial electrolysis takes place with liberation of gas bubbles that favor self-clearing of the perforated surface 4 and active circulation of the pulp slurry and ion-exchange sorbent in the electro-absorber. When saturated, the ion-exchange sorbent is unloaded from the plant and is sent to desorption using some known method.

Figure 2 shows the layout of the electro-absorber intended for application in the large-scale industrial plants.

![Figure 2](image)

**Figure 2.** Layout of the large-scale industry electro-absorber: 1—body of the electro-absorber; 2—pulp slurry pipeline; 3—vortex generators; 4—anode; 5—cathode; 6—mesh; 7—mesh; 8—sorbent discharge pipe; 9—discharge pipe; 10—gas outlet pipe; 11 and 12—stop valves.

The second-version electro-absorber is designed for noble metal recovery at large-scale plants. In this case, the ion-exchange sorbent granules are placed in the body 1 before the feed of the pulp slurry. When the pulp slurry flows through the vortex generators 3 installed in the pipeline 2, additional grinding of mineral particles unlocks dispersed gold. Then, in the electro-absorber, mineral particles collide and bump against the cathodes 4, and additional leaching of unlocked gold takes pace. The ion-exchange sorbent in the form of CN⁻ interacts with the mineral particles, dissolves unlocked gold particles and gets filled with them.

Then, the flow enters the second unit of the electro-absorber through the mesh 6. The mesh catches CN⁻ sorbent whereas the pulp slurry flows into the second unit with the ion exchange sorbent in the
form of OH⁻ for extra leaching of gold-and-cyanide complexes and toxic cyanides. When passing the anode–cathode system with the constant voltage maintained, destabilized ions go to the ion-exchange sorbent owing to electrodialysis. Oxygen is consumed in the boundary solution layer immediately adjoining gold ions. Further fruitful dissolving of gold is possible if the boundary layer is filled with the ion-exchange sorbent and oxygen from the entire volume of the solution owing to diffusion; the gold dissolving rate will be higher with the higher diffusion rate. Additional oxygen appears on the anode, which favors active leaching and absorption of gold. Gases are discharged via the pipe 10.

As a result, cations go to the cathode, interact with the new particles of the ion-exchange sorbent, generate new polyatomic gold anions and are caught by the sorbent. Or, vice versa, anions go to the anode where additional leaching of gold takes place. Under the combination effect of electro-osmosis and electroactivation of ion exchange, metal ions pass to gel phase of the ion-exchange sorbent. Also, the local ion flows and the associated magnetic microfields additionally intensify the ion-exchange absorption process. Owing to an increase in the local concentrations of ions, some gold ions deposit on the cathode 5 under effect of polarization in the area of the electric layer.

The ion-exchange sorbent OH⁻ granules are separated from the pulp slurry by the mesh 7. The pulp slurry, after electroactivation and electro-deposition in the second unit, freely flows through the mesh and is let out via the discharge pipe 9 at the flow rate ensuring the pre-set recovery efficiency. As the ion exchange sorbent is saturated, it is unloaded from the electro-absorber and fed to desorption.

The presented technology has been trialed on tailings of rebellious ore concentration at one of the mineral deposits in Transbaikalia. The tailings contain mainly dispersed gold. These gold fines are unrecoverable by leaching using a simple or oxygen-filled cyanide solution or by a regular ion-exchange sorbent. Low gold content of 1.1–1.3 g/t of these tailings prevents from application of any know metallurgical processing techniques.

Multiple trials have proved the efficiency of the proposed technology. Gold recovery has made 57.5%. Reduction in the environmental impact is achieved by application of the ion-exchange sorbent in the form of OH⁻ to recover toxic gold-and-cyanide complexes and cyanides at the late state of absorption. Furthermore, excess cyanides are oxidized on the anode down to cyanates that are less toxic for the natural environment.

The proposed technology implemented using the designed electro-absorbers favors minimization of waste and mitigation of the environmental impact.

References

[1] Aggravating Problem Connected with the Local Mining and Processing Industry Waste Official site of the Public Prosecutions Department of Transbaikalia, Russian Federation. Last visited: 24 November 2015

[2] Sekiosv AG and Mazurkevich SA 2005 RF Patent No 2251582 Noble metal recovery from solutions and pulp slurries and the reaction vessel Buill. Izobret. No 13