6.6. PROCESSING ENRICHMENT TAILS OF GOLD PLACER DEPOSITS («BLACK SANDS») WITH IODINE-IODIDE SOLUTIONS

Palval I. A. (PL Lucente LLC), Buchikhin E. P., Nesterov (VNIIHT) K. N., Bakhir V. M. (Vitold Bakhir Institute)

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Currently, there is an acute issue of processing «black sands» — the products of concentrate recovery of alluvial gold-bearing deposits or fine-grained rocks. This material belongs to the category of refractory minerals and does not lend itself to classical methods of processing.

The problem of gold extraction in this case can be solved either by a combination of fine or ultrafine grinding followed by a hydrochemical method of oxidative acid leaching, including autoclave, or by thermochemical opening of raw materials by the method of oxidative roasting followed by leaching of gold with an aqueous solution of a suitable reagent, including cyanidation.

The objective of this study was to develop a technology for the extraction of gold from «black sands», as applied to low-tonnage production in the field, ensuring the profitable operation of the company in an environmentally safe mode.

Preliminary studies have shown that this type of raw material is not amenable to cyanidation, even if it is preconditioned by firing. Thiosulfate leaching was also ineffective. Limitations of the possibility of gold recovery by oxidative leaching with hydrochloric acid solutions using nitrogen-containing oxidants (solutions of aqua regia) are associated with the need to maintain a high temperature (90°C), slowed down kinetics of the process and emissions of toxic nitrogen oxides.

The use of chlorine as an oxidizer requires the creation of special storage stations for bladder chlorine on site, the toxicity of the gas and the need to organize a complex gas cleaning system. Similar limitations exist for bromine leaching. The use of other oxidants is currently constrained by their high cost.

The intensification of the processes by using fine or ultrafine grinding requires energy-intensive and expensive grinding equipment (mills, screens, etc.).

A way out of this situation may be the use of iodine-iodide solutions. As it follows from the published literature data, the efficiency of gold leaching with iodine-iodide solutions is not inferior to both systems based on hydrochloric acid and those with the above oxidants. The solution of iodine in potassium iodide lends itself to electrochemical regeneration and can be used in circulation, the process is environmentally friendly. At present, it can be organized in the field by means of the devices manufactured by the Vitold Bakhir Electrochemical Systems and Technologies Institute which allow organizing the production of iodine and its reuse in the process of gold leaching.

The disadvantages of iodine-iodide technology are mainly associated with the high cost of reagents. This requires thorough washing of the cakes after leaching and separation of iodine from waste solutions. In addition, the development of a technology for iodine-iodide leaching of gold from «black concentrates» requires minimizing the consumption of iodine for the oxidation of impurities accompanying gold, which is associated with making provisions for preliminary conditioning of the concentrate. This requires knowledge of the material and mineralogical composition of the feedstock and the forms of gold in it.

The research presented in this article deals with the solution of the above tasks.

1. FEED CHARACTERISTICS

The study used a sample of «black sands» weighing 10.0 kg with a particle size of more than 93 % of +0.1 mm class (coarse fraction +1.0 mm was 21.2 %; fine fraction -0.05 mm was 2.3 %). Granulometric characteristics of the feedstock are shown in Table 6.6.1.

Due to the presence of a large amount of grade +0.40 mm with a total yield of 44.6 % in the concentrate sample for research, part of the material was previously subjected to additional grinding in a ball mill to a size of 95 % of grade –0.10 mm.

Table 6.6.1

Granulometric composition of the «black concentrate» sample

No.	Size grade, mm	Grade yield, %
1	+ 1.00	21.2
2	–1.00 + 0.40	23.4
3	–0.40 + 0.20	35.4
4	–0.20 + 0.10	13.2
5	–0.10 + 0.05	4.5
6	–0.05	2.3
7	Starting sample	100.0

X-ray phase analysis showed that the phase composition of raw materials was represented by the following minerals: magnetite ($FeO•Fe_2O_3$) — 47.8%; quartzite (SiO_2) — 32.9%; baddeleyite (ZrO_2) — 14.0%; titanomagnetite (Fe_2TiO_4) — 4.56%. Of these, magnetite and titanomagnetite were predominantly bearing finely disseminated gold. According to elemental analysis data, the gold content in quartzite and baddeleyite was insignificant. The average gold content in the feedstock was 36.1 g/t Au; gold content in a sample crushed to a size of –0.10 mm was 55.8 g/t Au.

2. CHEMICAL CONDITIONING OF FEEDSTOCK

This process is understood as the preliminary processing of feedstock by chemical or pyrometallurgical methods in order to oxidize all forms of reducing agents that can interact with iodine.

The main form of chemical depression of gold in the process of iodine leaching is «sluggish» dissolution of gold due to the absorption of the solvent — iodine by various metals of impurities (Fe, Cu, Zn, Pb, etc.). Since most of the impurities formed in the process of leaching iodine complexes of metals have good solubility, they significantly increase the total salt background of the solutions, which results in the formation of chemical films on the surface of gold grains that inhibit the process of gold dissolution. This, to a large extent, explains the decreased gold recovery into solutions during hydrometallurgical processing of ores containing chemical gold depressants.

In this part of the work, in order to exclude the depressing effect of by-product impurities, experiments were carried out on preliminary chemical conditioning of raw materials.

As the experiments carried out have shown, firing the material at a temperature of 700–750°C for 2 hours or processing with sulfuric acid in the presence of oxidizing agents (hydrogen peroxide or sodium nitrite) for 2 hours at 90–95°C almost completely solves the problem of iodine losses with reducing agents (iron, sulfur, etc.) — the iodine consumption during the subsequent process of leaching gold from «black sands» corresponds to stoichiometry.

3. EFFECT OF CONCENTRATE SIZE ON GOLD RECOVERY

It is known that the most common reason for the technological tenacity of gold ore feedstock is the fine dissemination of gold. According to the mineralogical analysis, finely dispersed gold in «black sands» is associated mainly with iron oxides and hydroxides, which are oxidation products of gold-bearing pyrite. In this regard, in order to increase the efficiency of concentrate processing and the degree of gold recovery, a series of experiments was carried out to leach samples of «black sands» of various sizes.

It has been experimentally established that optimal leaching results are achieved by grinding 98% of the material to a level of -0.1 mm, or -0.074 mm (200 mesh). Deeper grinding leads to an unjustified increase in energy consumption during grinding, and great difficulties in the pulp filtering and settling.

With regard to the above limits of particle sizing in production suspensions, the pulp filtration and sedimentation processes are successful with flocculants of the class of high-molecular polyamides being introduced into the system with a consumption of 5.0–6.5 g/t of solid. In this case, the process can be carried out in decantation mode, followed by filtration of the condensed product on vacuum nutsche filters, which is especially important for field production.

4. OPTIMIZING LEACHING CONDITIONS

This task in each specific case is fulfilled by the method of selection of concentrations and the ratio of concentrations of potassium iodide and iodine in leaching solutions, determination of the required leaching time and liquid to solid ratio. In our case, the optimal technological indicators of the gold leaching process with iodine-iodide solution from «black sands» are as follows:

- potassium iodide (KJ) concentration — 100g/l;
- iodine (J_2) concentration — 10g/l;
- temperature — 20–25°C;
- liquid-to-solid (mass.) — 2;
- leaching time — 1.5–2.0 h.

These conditions ensure gold recovery level of 78–80% in one stage of leaching.

For comparison, adaptation experiments were carried out on leaching gold from concentrate with various reagents: with a solution of «aqua regia» at a temperature of 90°C in 8 hours of treatment, the degree of gold extraction was 83–84%; leaching by the hydrochloric acid — chlorine system during the same processing time ensures the gold recovery level of 73–75 %.

5. PROCESS FLOW OF REGENERATION OF IODINE-IODIDE SOLUTION AFTER GOLD DEPOSITION FROM PRODUCTION SOLUTIONS

The process of gold precipitation from production iodine-iodide solutions was carried out according to the standard reduction technique in an alkaline medium using a reagent — hydrazine. It should be emphasized that after the gold precipitation operation and its separation by filtration, the filtration mother liquors are alkaline solutions of potassium iodide. Regeneration of the iodine-iodide leaching system involves the oxidation of this salt to the requirements of the optimal composition of the leaching reagent solution, namely 100 g/l KJ and 10 g/l J_2.

This process was carried out using a laboratory device AQUATRON-31-L-10 manufactured by the Vitold Bakhir Electrochemical Systems and Technologies Institute, producing the required amount of iodine from potassium iodide (in the anode chamber) together with caustic potassium (in the cathode chamber). The main characteristics of the device are shown in Table 6.6.2, the general view is shown in Fig. 6.6.1.

Table 6.6.2

Main characteristics of AQUATRON-31-L-10

Parameter name	Parameter value
Iodine performance	19 to 23 g/hour
Caustic potassium performance	16 to 18 g/hour
Time to reach operating mode at startup	15 minutes, no more
Consumed electrical power	400 watts
Supply voltage	220 volts, 50 Hz

Fig. 6.6.1. *General view of the experimental laboratory setup.*

6. POST-LEACHING CAKE WASHING

The need to solve this problem is determined by the high cost of iodine, which requires its complete return to the technological cycle. This is achieved by applying a three-stage water cake washing after gold leaching and iodine captured by the cake at a liquid-to-solid ratio of 1 (wt.) Through repulpation and subsequent filtration, gold is almost completely washed already at the first stage of water washing, iodine — after the third one.

Based on the above, a scheme was developed for the process of washing the leached cake from dissolved gold and chemical reagents: for potassium iodide (KJ) and iodine (J_2).

After the process of iodine-iodide leaching, the pulp enters the filtration, the production gold-bearing solution is accumulated in the receiving tank and enters the reagent gold precipitation with hydrazine.

Insoluble residue — cake (moisture 20 %), is sent to the 1st water wash. It is reloaded into the second reactor, where it is pulped with water to the ratio liquid-to-solid = 1, the resulting pulp is filtered off. The 1st wash water is directed to the receiving tank, and the cake is sent sequentially, first to the 2nd and then to the 3rd water wash, which are carried out in a similar way. After the end of the 3rd water washing process, the wet cake washed from gold and reagents (by 99.5 %) is sent to the tailings dump, and the 3rd wash water can be disposed of or reused at the stage of the 1st water washing.

The remaining 1st and 2nd washings from this operation are combined in one container and contain, respectively, 1.89 kg of J_2 and 19.25 kg of KJ. Therefore, it is recommended to send this wash water to the operation of sorption purification from iodine.

7. SORPTION WASTEWATER PURIFICATION FROM IODINE

The studies have shown that the anion exchanger Purolite S992 fully meets the requirements of the technology under development, as it has the iodine capacity 0.916 to 0.970 g/g. The experiments have shown that to saturate the resin, 12 hours of contact are required at a sorbent-to-solution volume ratio of 1: 4000. Residual iodine content in the sorption mother liquor is 10 to12 mg/l.

Desorption of iodine from the saturated sorbent was carried out with a solution of the composition: NaOH (20 g/l) + sodium sulfite Na_2SO_3 (75 g/l) with a consumption of 10 volumes of desorbing solution per volume of resin. Commercial desorbate (4 volumes) is used to isolate iodine and its return to the technological cycle, barren desorbing solutions (beginning and end of desorption) are used to prepare fresh desorbing solutions.

CONCLUSION

Based on the studies performed, we propose the following process flow for gold-containing «black sands» treatment using iodine-iodide technology (see Figure 6.6.2).

The process flow design was tested on a laboratory scale and on an enlarged pilot scale. Figure 6.6.3–6.6.6 shows some of the different devices and tank equipment for direct testing, and those produced by the PL Lucente Company in Zelenograd (Russia). Gold leaching tests using iodine-iodide systems were carried out on batches of tailings from the enrichment of placer deposits in the Magadan region and the Sokha River at the PL Luchente Company in 2017–2018.

The analysis of the results of the work carried out during the processing of a technological sample with a total mass of 2.0 tons with an average content of 55.8 g/t Au, showed that the consumption of sulfuric acid in the operation of preliminary chemical conditioning was 20%, the oxidizer of sodium nitrite was 5%. The average gold recovery in the production iodine-iodide solution was 83–85% Au at the specific consumption of leaching reagents per 1 ton of raw materials: J_2 = 0.6 kg/t, KJ = 0.1 kg/t.

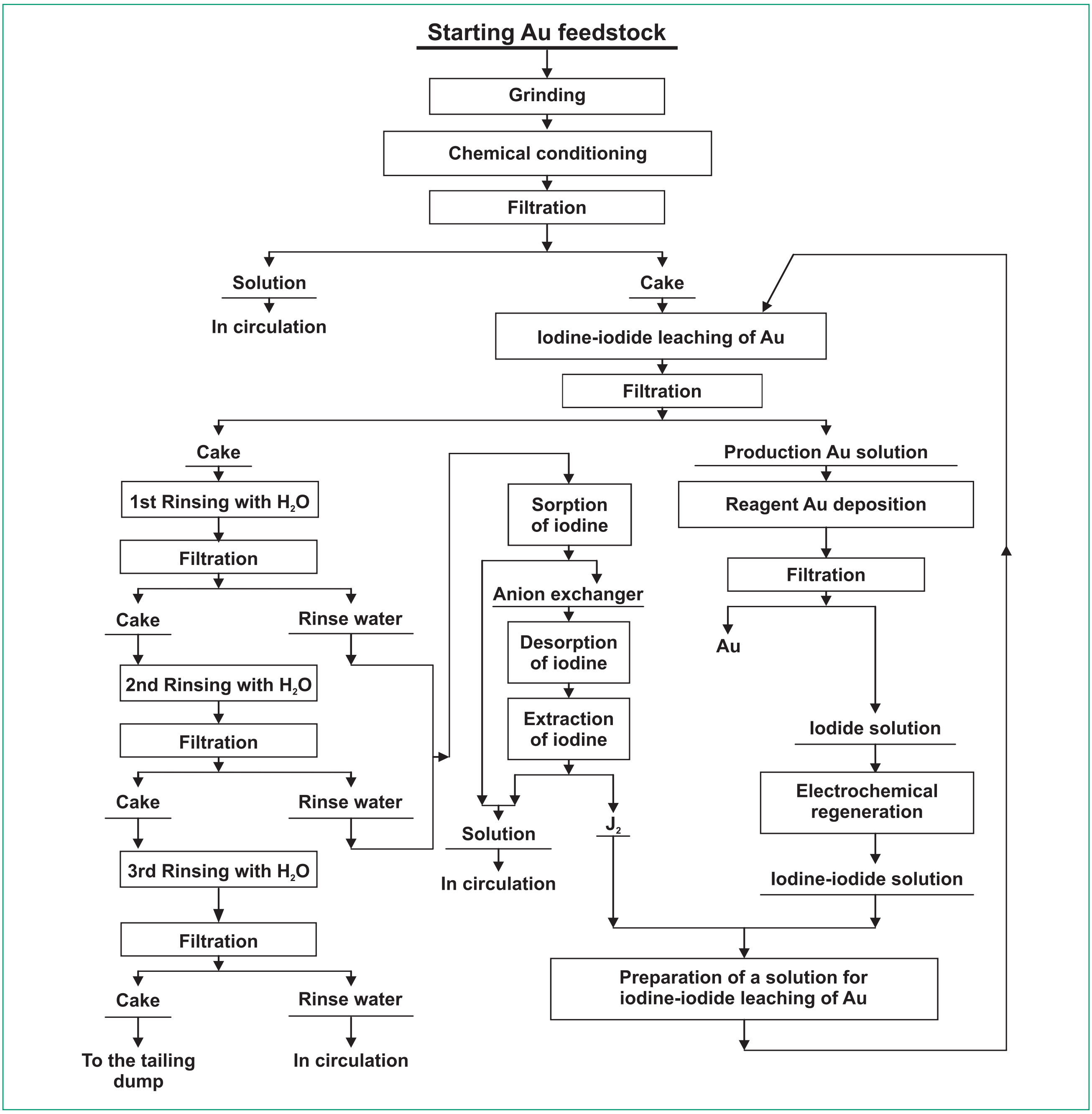

Fig. 6.6.2. Basic flowsheet for processing gold-containing «black sands»

Fig. 6.6.3. Nutsche filter.

Fig. 6.6.4. Leaching reactor.

Fig. 6.6.5. Gold precipitation reactor.

Fig. 6.6.6. Device for electrochemical regeneration of iodine-iodide leaching solution

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Э45

Bakhir V. M., Panicheva S. A., Prilutsky V. I., Panichev V. G.

Э45 ELECTROCHEMICAL ACTIVATION:
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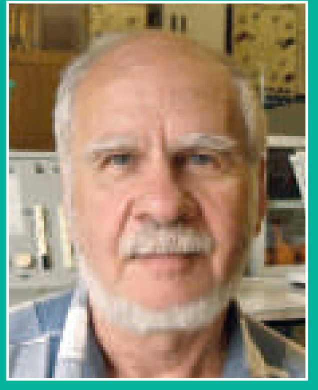

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BAKHIR V. M.
PANICHEVA S. A.
PRILUTSKY V. I.
PANICHEV V. G.

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