Results and Their Interpretation of the Pilot Testing of the Developed Technology for the Extraction of the Precious Metals

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Abstract

The important nature-protection value, when developing the mineral deposits, belongs to the technologies directed first of all on the increase of extraction of useful components from the ore minerals at reducing the volumes of dump products and decreasing therein the content of harmful admixtures that considerably reduces a level of contamination to the environment and the other negative ecological effects [1–6]. Taking into account dramatically increasing requirements to the environmental protection, there have been developed the low-waste technology to extract gold and silver from gold-containing quartzites with the use of waste waters in circulation. In conducting pilot tests to improve the reliability of quantitative determination of valuable components from ore, is the use of reliable and accurate sampling system. Thus large amounts of ore are being processed [7,8]. And as critical is the accuracy of the analytical methods for the determination of these valuable components in the original ore, as well as in the intermediate products of enrichment, the final concentrate and final tails. In the presence of free gold in the ore in determining it from hard products and rock ores the error probability increases significantly [9,10]. The purpose of this research was to test the technology developed in the enrichment of gold quartzite in semi- industrial conditions, as well as the interpretation of analyses' results when testing enrichment's technology of precious metals from gold quartzite . The results of process studies of ore showed that the most effective of the tested methods appeared to be the direct cyanidation of crushed ore up to 95% cl. –0,08 mm. In this regard, the extraction of gold ranges from 91,7% to 100% , and silver – from 48% to 68% and with content of precious metals in dump cakes left the traces – 0,2 g/t on gold and 9,7–6,4 g/t on silver accordingly. A scope of processed ore, a study of all the factors at desalinization of precious metals, milling fineness of the ore, influence of the pulp density, concentration potassium cyanide and lime as well as the kinetics of the process, allow insisting that the obtained results will be fully reproduced at the industrial processing of quartzites of the field, but they are also may be used for designing the mobile module unit to extract precious metals for the given type of ores [11–14].

Keywords: development of environment-oriented technologies, gold and silver recovery, solvent extraction, the interpretation of analyses' results

Experimental part

The subject of research appeared to be an ore sample represented with secondary quartzites having the industrial value. As for material composition, the quartzites sample being investigated refers to a type of gold-quartzy ore with small sulphide-content mineralization. The main industrially valuable component is gold (2,3 g/t) and pari passu silver (18,9 g/t). A certain value is represented by quartz as the raw material to produce silicate walling materials, because nonmetallic minerals by 85,4% are represented with quartz with small content of barite [9,11]. Clay minerals and sericite present with no more than 5,5% that opens an opportunity to wash out dissolved gold and silver as per a scheme of continuous countercurrent decantation. The data of phase analysis show that the gold in ore is in vast majority (over 90%) in a form being accessible for desalinisation in cyanide solutions, and with increasing the milling fineness, the amount of gold being cyanated is slightly increased due to its release from intergrown pieces with rock-forming minerals. Absolute amount of non-cyanated gold and silver is 0,1 g/t and 9,0–7,0 g/t accordingly. Distribution of precious metals as per the class of ore size crushed to -2 mm shows that in the class of –0,04 mm, the gold and silver is approximately double concentrated due to its release from intergrown pieces. As for morphology, the gold in ore is quite pure and is in a free state with sizes from 0,00 mm to 0,3 mm. A shape of gold grains is irregular, and tufaceous-laminar formations are present more seldom. Singular gold grains have a wire-shaped form, and table-faced gold crystals are met very seldom but sometimes there are observed reduced arborescent crystals. Color – yellow, which is typical for high karat gold (900–950). Just singular grains have 750 purity [9,11]. Silver in ore is represented with argentite with fine connection with chalcosine and covelline and is in alloys with gold and appears in the free form of singular grains. Based on study of the material content of the form of availability of gold and its morphology there were made preliminary conclusions [11,15,16] regarding inexpediency to use gravitation methods and perspective of the ore processing with methods of desalinisation.

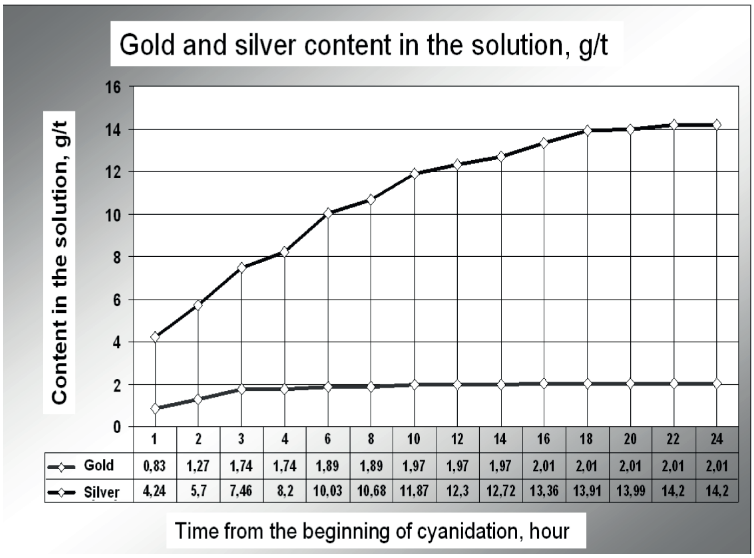


Fig. 1. Gold and silver content in the solution (g/t)

Rys. 1. Zawartość złota I srebra w roztworze (g/t)

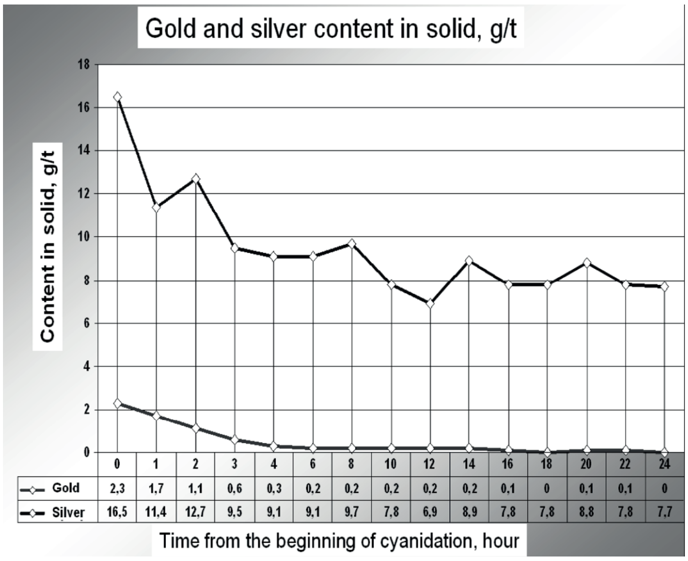
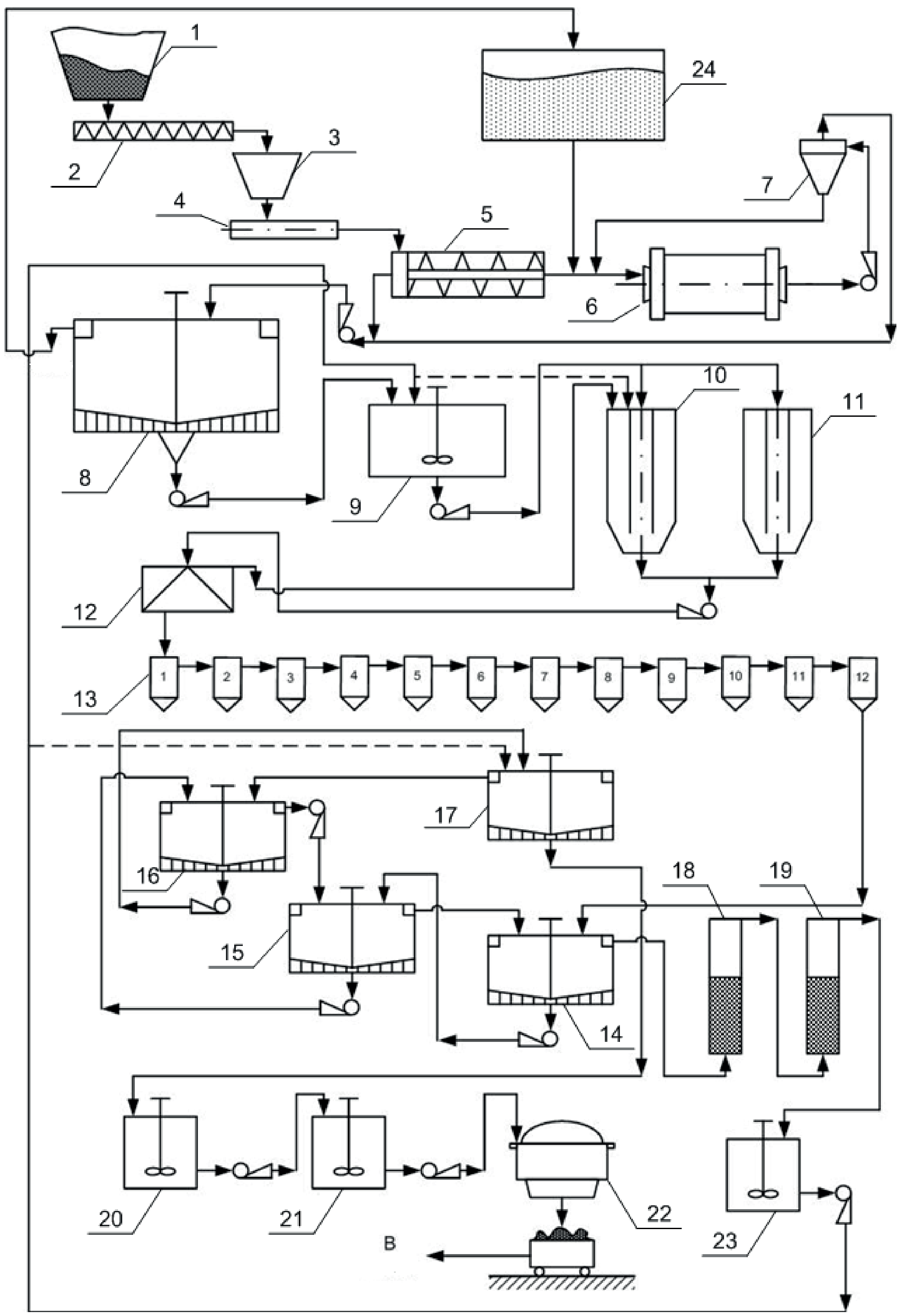


Fig. 2. Gold and silver content in solid (g/t)

Rys. 2. Zawartość złota i srebra w fazie stałej (g/t)

As the results of technological investigations the following was determined: in spite of presence in ore of some large-sized gold (up to 0,3 mm), by the method of gravitation it is possible to have at output a concentrate of 1,6% containing just 21,9 g/t of gold and 27,9 g/t of silver at extraction of 13,9% and 2,6% accordingly that points to a small efficiency of the gravitation process for the given ore with applying ordinary gravitation equipment. At flotation ore concentration, it is possible to extract to concentrate gold dust for 73,1% and silver for 48,4%; in this regard the content of precious metals in the tails of flotation remains considerable and is 0,8 g/t for gold and 10 g/t for silver.

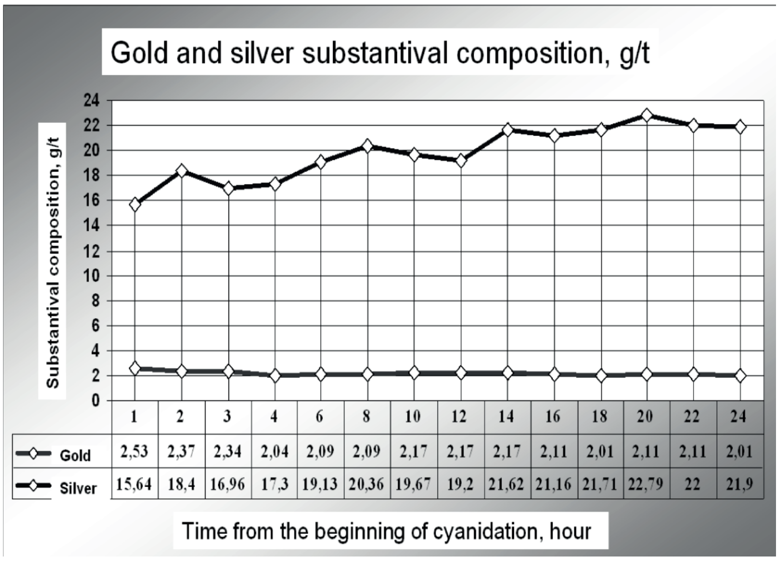
In desalinisation of precious metals there have been studied in details the influence of all the factors on their extraction and determined that at direct cyanidation of ore under optimum conditions it is possible to extract to cyanide solutions up to 99% of gold and 63% of silver [11]. The aim of study was to verify the developed technology of concentration of gold-content quartzites in semi-industrial scale and investigation of a full water circulation in conducting the technological process. In order to clarify the main factors of the process of cyanidation in the inductrial scale there was initially conducted the cyanidation of ores under periodic conditions [8,11]



Legend: 1–,3–ore hopper , 2–, 4–feed belt, 5–screw-type classifier, 6–grinding mill, 7–hydrocyclone, 8–big thickener, 9–Deveraux agitator, 10–, 11–pachuca agitators, 12–surge tank, 13–(1–12) pachucas, 14–1st thickener, 15–2nd thickener, 16–3rd thickener, 17–4th thickener, 18–, 19–sorption columns, 20–, 21–, 23–Deveraux agitator, 22–final tailings tank, 24–accumulator tank, B–tailings go to

Fig. 3. The scheme of devices' chain during the pilot testing of cyanidation and scheme of the pulp's countercurrent decantation in the thickeners' system

Rys. 3. Schemat technologiczny sieci pilotażowej podczas testów instalacji cyjankowej i systemu dekanatacji zawiesiny w przeciwprądzie w układzie zagęszczaczy



	1	2	3	4	6	8	10	12	14	16	18	20	22	24
Gold	2,53	2,37	2,34	2,04	2,09	2,09	2,17	2,17	2,17	2,11	2,01	2,11	2,11	2,01
Silver	15,64	18,4	16,96	17,3	19,13	20,36	19,67	19,2	21,62	21,16	21,71	22,79	22	21,9

Fig. 4. Gold and silver substantival composition (g/t)

Fig. 4. Skład sumaryczny srebra i złota (g/t)

Kinetics of cyanidation was carried out in parallel with two blenders of a 90 liters capacity at concentration of potassium cyanide of 0,08–0,1% and lime of 0,02%. Obtained data (table 1) show that the content of gold in the tails after 6–8 hours of cyanidation decreases up to 0,2 g/t and of silver – up to 9,1–9,7 g/t. Herewith, the extraction of gold oscillates from 91,7% to 100%, and of silver – from 48% to 68% with content of precious metals in dump cakes of cyanidation left traces – 0,2 g/t of gold and 9,7–6,4 g/t of silver accordingly (Fig. 1).

Upon assigning the kinetics of the process, ore's cyanidation was carried out in the continuous flow as follows: a pulp with density of 32–35% (solid) was pumped to the agitator of 90 liters capacity. Lime with concentration of 0,01–0,02% and cyanide (cyanide of potassium) with concentration of 0,1% were also dumped in the agitator.

Through the depulping machine of "Segner wheel", the pulp was delivered to the first pachuca (in this regard the volume of pulp – 30 l/hour), and the residual flow of pulp returned by gravity to pachuka of preliminary cyanidation. The main cyanidation was performed in the 12 series connected pachukas of a 35 l capacity each and cascade installed on a special frame. A time of cyanidation in pachukas was 16 hours. During cyanidation there was processed about 6 tones of ore. Sampling of supply for gold and silver, density of pulp and screen analysis of ore on the class -0,08 mm were performed at pumping the pulp from a 800 l pan to the 90 l pachukas. Every hour there was analyzed a discharge of the tailing (12) pachuka. Individual samples were united to average-shift ones (8 hours) and analyzed for gold and silver. The use of waste waters in circulation was checked in semi-industrial tests. Tests on desalinisation in the continuous flow lasted within 11 days (Fig. 1, Fig. 2, Fig. 3).

Waste waters obtained in processing of quartzites are summarized from the liquid phase of discharge from condensation of crushed ore, gold-free mixtures after sedimentation of metals and liquid phase of dump cakes of cyanidation. During the period of tests, the cycle-by-cycle water circulation was tested in the cycle of crushing (6 turns) and washing out of dissolved metals with a delivery of gold-free mixtures to densifier No. 4 (6 turns). Besides, the mixtures after sedimentation of metals were used in cyanidation. In the course of tests there was monitored a dynamics of the salt accumulation in recirculated waters and their influence on the process of washing out of dissolved metals and cyanidation. A characteristic of recirculation waters is given in [11].

Results

The analysis of obtained data shows that the ionic content of cycle water circulation in crushing is almost no changed, excluding some accumulation of sulphates, iron, potassium and natrium. It has to be noted that the quartzites to be processed are characterized with relatively simple mineral content and as the obtained liquid phase as a result of contact of water with ore is slightly mineralized. In a small amount there are presented the ions of non-ferrous metals (lead, zinc, copper), potassium and chlorides. From this point of view, the liquid phase to be formed as a result of processing of the gold-containing quartzites is favorable in its use in the turns. Changes in the ionic content of recirculation waters obtained after sedimentation of metals and used in washing out of dissolved gold and silver are also insignificant [9,11]. Perhaps, some improvement of the liquid phase takes place but it was not detected, therefore the mixtures without losses for values may be directed to washing out. Silver is insignificantly accumulated at repeated use of water. Thus, after 10 shifts of the unit operation, its content increased from 0,05 mg/l to 0,5 mg/l. The data of washing out of dissolved gold and silver based on fresh water (content of gold in mixture – 1,11м mg/l; of silver – 6.2 mg/l) as well as with introversion of mixtures (content of gold in mixture – 1, 28 mg/l; of silver – 6,0 mg/l) show that the results in both of the cases are actually the same. Gold-free mixtures with concentration of potassium cyanide of 0,06–0,012% were directed to cyanidation of the initial ore without deactivation [11]. Its deliver to a head of the process makes the content of cyanide decreased (Fig. 1), (Fig. 3). Interpretation of results of analyses of sampling when carrying out pilot tests, show reliable, valid data are obtained (Fig. 1, Fig. 2, Fig. 3) [7,11]. The process chart of the ore processing provides for condensation of the pulp prior to its coming for cyanidation, condensation at washing out of dissolved metals as well as sedimentation in the tiling pit. In using the water in the turn with the purpose of studying the conditions of dewatering of the ore pulp and determination of necessary area of condensation, there was monitored the kinetics of sedimentation of suspended particles of crushed ore (pH = 7,1) and cyanide pulp (pH = 10,8). Calculated specific areas of sedimentation, which are for crushed pulp 2,1 m^{2}day/t and for cyanide pulp – 1,1 м^{2}x m^{2}day/t show that condensation of cyanide pulp flows more effectively almost twice.

A role of coagulating agent is played by a lime used at cyanidation. Comparing the obtained results with the reference data it may be concluded that the pulp of secondary quartzites is comparable on condensability with standard pulps, in which the content of clay substances is small [7,11]. Condensed pulp with density of about 50% of solid in pumping to pachukas of 90 l capacity was diluted with gold-free mixtures of up to 32–35% of solid. The results of cyanidation are evidence that during the whole period of tests, the content of gold and silver in the cyanidation cakes stay at the same level. Thus, the liquid phase obtained in processing of secondary quartzites may be repeatable used in the turn without decreasing the process values. Washing out of dissolved gold and silver was carried out as per the scheme of continuous countercurrent decantation from the tails of cyanidation with sedimentation of gold and silver from the discharge of the 1st densifier based on anion exchange resin AM-2B [17–20] (Fig. 3). A method of continuous decantation on the system of countercurrent is widely applied in many cases of the modern practice; there are processed the ores not containing considerable amounts of clay material. A scheme, which was checked at performing the continuous countercurrent decantation of pulps in the system of densifiers, is given in Fig. 3. After cyanidation the pulp is successively delivered to 4 densifiers where it is washed out: in 4 – with gold-free mixtures after sedimentation of metals, in 3 – with discharge waters from the 4th densifier, in 2 – with discharge waters of the 3rd densifier, and in 1 – with discharge waters from the 3rd densifier. In this regard, the direction of movement of the pulp being pumped was reverse toward to the water flow. Condensed product of the 4th densifier is the dump product of improvement and after dewatering it was directed for study and possibility of application as the raw material to produce silicate walling materials. Discharge of the 1st densifier being a mixture improved with precious metals, was directed to sedimentation of gold and silver into two sorptive columns connected in series between each other. Obtained data checked in semi-industrial scale on washing out of dissolved gold and silver as per scheme of continuous countercurrent decantation show that as a result of the four stages of washing out in discharge of the 4th densifier there contents 0,106 mg/l of gold and 0,72 mg/l of silver accordingly (with content of precious metals in discharge of the 1-st densifier of 0,46 mg/l and 2,53 mg/l accordingly), i.e. a degree of washing for gold is 77–78% and for silver 71–72%. It is obviously that the use for washing out of the densifiers with a 160 l capacity is not quite effective. At the same time, in a number of shifts the content of gold in solid oscillates from traces to 0,1 g/t (Fig. 2). Tracing contents of gold give evidence about a full washing out of dissolved gold.

Conclusions

1. In conducting pilot tests to improve the reliability of quantitative determination of valuable components from ore, is the use of reliable and accurate sampling system. Thus large amounts of

ore are being processed. And as critical is the accuracy of the analytical methods for the determination of these valuable components in the original ore, as well as in the intermediate products of enrichment, the final concentrate and final tails. In the presence of free gold in the ore in determining it from hard products and rock ores the error probability increases significantly.

2. Interpretation of results of analyses of sampling when carrying out pilot tests, show reliable, valid data are obtained.

3. The results of process studies of ore showed that the most effective of the tested methods appeared to be the direct cyanidation of crushed ore up to 95% cl. – 0,08 mm. In this regard, the extraction of gold ranges from 91,7% to 100% , and silver – from 48% to 68% and with content of precious metals in dump cakes left the traces – 0,2 g/t on gold and 9,7–6,4 g/t on silver accordingly.

4. A study of continuous process of counter-current washing out of the tails of desalinisation with sedimentation of gold and silver from the discharge of the 1st densifier based on anion exchange resin AM-2B allowed to make a conclusion being very important from the point of view of the environmental protection, about an opportunity of repeatable use of metal-free mixture in the course of desalinization and washing out of dissolved precious metals without reduction of the technological parameters. The ionic content of the cycle water circulation is insignificantly changed and the liquid phase obtained in processing of secondary quartzites may be used six times in the turn.

5. A scope of processed ore, a study of all the factors at desalinisation of precious metals, milling fineness of the ore, influence of the pulp density, concentration potassium cyanide and lime as well as the kinetics of the process, allow insisting that the obtained results will be fully reproduced at the industrial processing of quartzites of the field, but they are also may be used for designing the mobile module unit to extract precious metals for the given type of ores.

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Wdrożenie technologii wydzielania metali szlachetnych w instalacji pilotowej – wyniki i ich interpretacja

Podczas eksploatacji złóż mineralnych bardzo ważnym aspektem jest ochrona środowiska. Dlatego obecne technologie koncentrują się na zwiększeniu uzysku składników użytecznych z jednoczesnym obniżeniem ilości odpadów. Dzięki temu redukuje się ilość szkodliwych odpadów, a co za tym idzie obniża się również poziom zanieczyszczenia środowiska oraz innych negatywnych oddziaływań ekologicznych [1–6]. Biorąc pod uwagę gwałtowny wzrost wymogów dotyczących ochrony środowiska, opracowano niskoodpadowe technologie pozyskiwania złota i srebra z kwarcytów bogatych w złoto. W testach pilotażowych, mających udowodnić wiarygodność wyników badań ilościowych cennych składników rudy, ważne jest wykorzystanie niezawodnego i dokładnego systemu poboru próbek. W tym celu przetwarza się znaczne ilości rud [7,8]. Dokładność jest kluczowym aspektem metod analitycznych w dążeniu do określenia cennych składników rudy, jak również końcowego składu i ilości odpadów. Przy określaniu ilości złota rodzimego ze skały zwięzłej ryzyko błędu znacząco wzrasta [9,10]. Celem niniejszych badań było sprawdzenie opracowanej technologii wzbogacania kwarcytu złotonosnego w warunkach pół-przemysłowych, jak również opracowanie analiza wyników testów technologicznych wzbogacania złota z kwarcytu. Wyniki badań pokazały, że najefektywniejszą z badanych metod okazała się bezpośrednia cyjanizacja kruszonych rud do 95% poziomu ufności – 0,08mm. W wymienionej metodzie, uzysk złota waha się od 91,7% do 100%, a srebra – od 48% do 68%, wraz z zawartość metali szlachetnych w spiekach odpadowych – odpowiednio 0,2 g/t złota i 9,7- 6,4 g/t srebra. Zakres badań nad przetwórstwem rud, jak również nad wszystkimi czynnikami ważnymi dla ługowania metali szlachetnych, mielenia rud, wpływu gęstości pulpy, stężenia cyjanku potasu i wapna, jak również kinetyki procesu, pozwala na stwierdzenie, że uzyskane wyniki mogą być w pełni powielone przy przetwórstwie przemysłowym złoża kwarcytu, oraz że można je wykorzystać do projektu modułu mobilnej jednostki przerobu metali szlachetnych dla określonego typu rud [11–14].

Słowa kluczowe: wdrożenie technologii ekologicznych, odzysk srebra i złota, ekstrakcja rozpuszczalnikowa, interpretacja wyników analizy