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Diversification of uranium production in order to extract associated precious metals

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Abstract. Work aimed at diversification of production through the extraction associated with valuable metals in the uranium mines. The peculiarity of this work is the additional processing of spent and existing blocks using the existing production infrastructure for the extraction of associated useful components. Underground leaching technology is well developed for uranium deposits. The technology of underground leaching of associated components differs only in the reagents used, hardware design, etc., but they are fundamentally similar in the method of extraction. Even if there are associated components in the uranium-bearing Sands with a content of less than 1 g/t, up to 0.1 g/t production can be profitable. In this regard, the use of ready-made infrastructure of spent blocks in the uranium field allows us to expect good economic profitability in the future.

Keywords: uranium mines, associated valuable metals, associated useful components, underground well leaching, productive solution.

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Introduction

The bowels of the Republic of Kazakhstan contain about 25% of the world's proven uranium reserves. A unique feature of uranium reserves is that 75% of them are concentrated in deposits associated with regional formation oxidation zones, which can be mined using a relatively cheap and environmentally preferred method of underground well leaching.

The development of the uranium mining industry of Kazakhstan is associated with the solution of major scientific and practical problems. Each of the fields has its own specific features, which makes it necessary to carry out certain volumes of scientific research not only in the process of developing new ones, but also when applying known technical solutions. These circumstances objectively determine the high science intensity of uranium mining.

Literature review

The uranium mining industry of Kazakhstan has a significant in size and fairly well-explored mineral resource base. Deposited underground borehole leaching (UL) systems [1].

As a rule, a number of noble and precious metals, such as gold, vanadium, rhenium, selenium, germanium, scandium, etc., which are not currently extracted, are simultaneously contained in uranium ores. The analysis carried out in a number of studies showed that there are prerequisites and grounds for involving in the technological cycle the extraction of associated valuable components contained in them from spent uranium blocks - gold, germanium, scandium, etc. The economic effect of the extraction of these metals in total can be no less than that of uranium, and taking into account the possibility of using the already constructed uranium production infrastructure, the extraction of these elements after uranium extraction can be economically justified. It is especially valuable that this process can be combined technologically and organizationally with the reclamation of spent blocks, which is especially important from an environmental point of view. The main advantages of the method of downhole leaching of uranium in comparison with traditional mining methods of field development are as follows:

- the possibility of involving in the operation of poor and off-balance ores of deposits with complex geological and hydrogeological conditions;
- insignificant capital investments and terms for commissioning deposits;
- improved working conditions, reduction in the number of workers compared to the mine method;
- the negative impact of production on the environment is reduced.

Currently, in the processing of polymetallic ores, a multi-stage hydrometallurgical process is used, with the help of which uranium, gold, rare and rare-earth metals are extracted.

In the technology for the extraction of uranium, gold, rare and rare earth metals, the main role is given to hydrometallurgical processes, since the content of uranium, thorium, tantalum and niobium, zirconium, molybdenum, gold and rare earth elements in ores is small and the use of pyrometallurgical processes is groundless. [2].

Hydrometallurgical processes have several advantages:

- their application provides selective extraction of metals from poor and hard-to-concentrate ores with minimal reagent costs in simple equipment at low temperatures. Hydrometallurgical methods can also be used for processing technogenic deposits (tailings of concentration plants, old dumps), which in some cases may be more cost-effective than processing existing deposits;
- the economic efficiency of hydrometallurgical processes has increased due to the development and implementation of such selective extraction methods as ion-exchange processes, extraction, the use of filterless circuits, autoclave oxidative leaching, etc. [3].

To obtain useful components from “poor” productive solutions with concentrations of less than 1 mg / dm^3 in terms of the content of the useful component, it is recommended to use methods for intensifying the underground well leaching process, which, in addition to the current methods, can be the following methods:

1. Increasing the redox potential of leaching solutions, as an option - introducing an additional oxidizing agent (oxygen, ozone, etc.) directly into the ore horizon through the injection well or increasing the oxidizing ability of the leaching solution supplied.
2. Overlaying on a solution containing a valuable component, potential differences, both on the surface (electrolysis cells) and directly on the leaching area (in the ore horizon).
3. The use of liquid extraction in conjunction with a high-performance tubular extractor.
4. Selection of the most optimal grade of ion-exchange resin for each of the required useful components along the way (or for their sum to obtain a collective concentrate with its subsequent separation into constituent elements).
5. The use of membrane technologies should be considered a promising direction due to the cheapening of basic structural materials - nanostructured polymers and plastics. The use of nanofiltration of "poor" productive solutions to obtain incidentally useful components in cost-effective concentrations.

A known method for the extraction of gold from concentrates, including leaching of concentrates with sulfuric acid solutions containing thiocarbamide, in the presence of an oxidizing agent is hydrogen peroxide. The leaching process is carried out in two stages. Extraction of gold from solutions after leaching was carried out in an electrolyzer with plate titanium cathodes (extraction of gold in the cathode deposit 70-80%). After electrolysis, gold was recovered by sorption on activated carbon. [4]. The main disadvantage of the considered method for the extraction of gold from concentrates is multi-stage (two stages of leaching and two stages of extraction of precious metals from the leaching solution) and, as a result, large volumes of processed solutions, loss of thiourea at the stages of sorption and electrolysis.

In [5], the results of studies on the leaching of gold from crushed ore to a fineness of -12 + 0 mm are presented. The use of sodium acetate as a chemical additive in the leaching of gold in a bottle test from crushed ore to a grain size of -12 + 0 mm increases gold recovery by ~ 4% and improves the kinetics of gold dissolution.

Sorption extraction of rare earth elements seems most appropriate at the stage of primary concentration. A serious problem in the sorption extraction of rare-earth elements from technological and productive solutions with pH =

0.5 ÷ 2.5 is the presence of a large amount of iron (III) and Al in them, since it is known that such a medium is non-selective for the separation of iron (III) and Al (as the most interfering impurities) from rare-earth elements, both at the sorption stage and at the desorption stage [6]. In practice, the task of extracting rare earth elements from such solutions is solved by hydrolytic deposition of iron (III) and Al with alkaline agents, with further organization of the process of extracting rare earth elements from clarified solutions, or from hydrated pulps, which was reflected in the method [7]. The disadvantages of this method include the large loss of rare-earth elements (20 ÷ 25%), due to coprecipitation with iron (III) and Al hydroxides, the use of strong solutions of precipitants, their high consumption, the formation of hardly processed waste water.

Another method is a preliminary reduction in a solution with pH = 0.5 ÷ 2.5, the most disturbing impurity of iron (III) to iron (II) - with iron shavings, urea, sodium sulfite, etc. With this organization of the process, the choice of sorption systems with significant separation coefficients of iron (II) and rare-earth elements (III) is much wider [8]. The disadvantage of this method is a change in the chemical composition of technological solutions with a high consumption of reagent reductants.

At the same time, in a number of industries maintaining a high concentration of dissolved iron (III) is dictated by technological necessity, because its presence contributes to an increase in the leaching (oxidizing) ability of solutions [9]. Therefore, the development of a method for the selective extraction of rare earth elements from solutions with pH = 0.5–2.5 containing iron (III) and Al without changing the chemical composition of the solutions is an extremely urgent task.

The known method [10], in which the extraction of rare earth elements from the technological solution pH = 0.5 ÷ 2.5, is carried out by sorption on gel sulfocachyonite KU-2. The rough concentrate obtained after precipitation contains%: rare earth elements - 1; iron - 2.0-2.2; aluminum - 15-18; water - 82. Next, a reprecipitation stage is proposed with the aim of bringing the draft concentrate of rare-earth metals to commercial output 30-40%.

The main disadvantages of this method is the low selectivity of the capacity of sulfocationite according to the amount of rare earth elements, and, therefore, the complicated subsequent operation of bringing the rough concentrate of rare earth elements to marketable products. These shortcomings lead to the need to use additional equipment - reactors for dissolving hydrates, filters for filtering a large number of intermediate products, as well as to the additional consumption of a rather expensive reagent - alkali during aluminum leaching. In addition, the degree of extraction of rare earth elements by this method is quite low - the yield is 60%.

Of the known analogues, the closest to the claimed invention in terms of features and purpose is a method of extracting rare earth elements from sulfuric acid leaching solutions [11] - adopted as a prototype. The prototype method includes sorption of REE from solutions with a complexing ion exchanger containing monodiglycolamide (MonoDGA) as an active component, desorption of REE with a solution of sulfuric acid with a concentration of 20-100 g / dm^3 to obtain a desorbed complexing ionite, which is sent to re-sorption of REE and desorption solution, which is sent for further processing.

The disadvantages of the method include the low capacity of the complexing ion exchanger for REE, which makes the further desorption solution process unprofitable.

Experimental part

Analyzes were carried out to determine the concentration of related elements in the composition of the combined technological solutions. The results of the analysis are presented in Tables 1-2. From the obtained data, a number of REE elements with the

Table 1 - The concentration of related elements of technological solutions

№	Combined Sample	Al, mg/ dm^3	Ca, mg/ dm^3	Mg mg/ dm^3	Fe, mg/ dm^3	Mn, mg/ dm^3	Co, mg/dm^3	Cu, mg/ dm^3	Mo, mg/ dm^3	V, mg/ dm^3	Σ РЗЭ, mg/ dm^3
1	Block 1	990,42	492,24	1433,10	3134,00	78,99	0,85	0,19	0,23	21,10	**21,80**
2	Block 2	824,71	491,20	1272,10	2791,70	76,62	0,81	0,10	0,16	14,48	**17,36**
3	Block 3	748,74	466,99	1283,40	2563,90	69,40	0,72	0,18	0,16	13,22	**16,13**
Average concentration		854,63	483,47	1329,53	2829,86	75,05	0,79	0,157	0,18	16,26	**18,43**

Table 2 – The concentration of rare earths with the highest content

№	**Combined Sample**	**La, mg/ dm^3**	**Ce, mg/ dm^3**	**Nd, mg/ dm^3**
1	Block 1	3,96	9,87	3,70
2	Block 2	3,19	7,89	2,91
3	Block 3	2,95	7,36	2,74
Average concentration		3,36	8,37	3,12

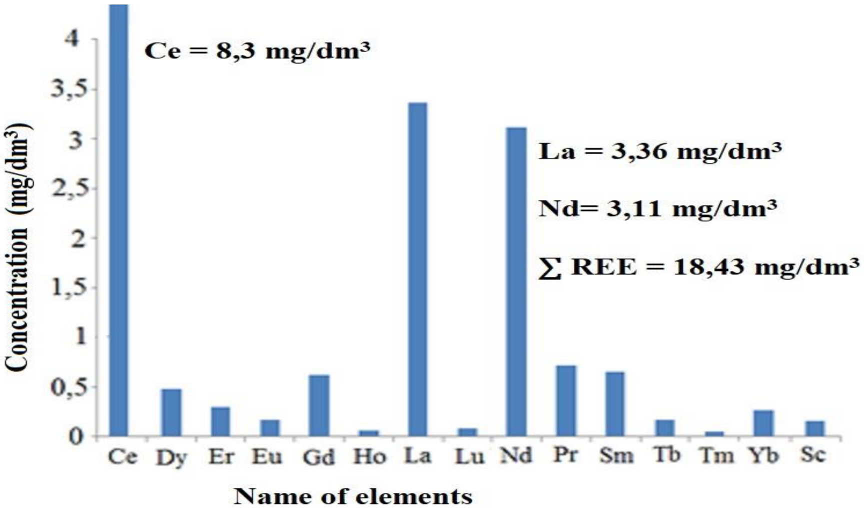

Figure 1 Distribution of REE by the average value of concentration in samples

most pronounced concentration indices can be distinguished; these are cesium (Ce) 8.37 mg / dm^3, lanthanum (La) and neodymium (Nd) with 3.36 and 3.11 mg / dm^3, respectively. REE concentration distribution is shown in Figure 1.

It is worth noting that the amount of rare earth elements is 18.43 mg/dm^3.

Determination of the concentration of gold (Au) in the composition of the combined technological samples

Research to determine the gold content in technological samples was carried out in the laboratory "Technologies for the hydrocarbon and mining and metallurgical sectors and related service industries" JSC "Institute of Metallurgy and Ore Beneficiation", Satbayev University in Almaty. The analyzes were performed according to the methodology (Measurement Technique reg. No. KZ 07.00.01996-2014) on a Varian AA240 atomic absorption spectrometer. From the results of the analysis, it was found that in block № 1, 0.20 mg/l of gold was found.

Conclusions

Features of the technology of downhole leaching and the availability of finished mining infrastructure of mines makes the diversification of the production of uranium mines for the extraction of useful associated components from the spent ore blocks of a uranium deposit promising and economically justified.

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Ілеспе бағалы металдарды өндіру мақсатында уран өндірісін әртараптандыру

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Түйіндеме. Жұмыс уран кеніштерінде ілеспе құнды металдарды алу есебінен өндірісті әртараптандыруға бағытталған. Жүргізілетін жұмыстың ерекшелігі ілеспе пайдалы компоненттерді өндіру үшін қолданыстағы өндірістік инфрақұрылымды пайдалана отырып, пайдаланылған және жұмыс істеп тұрған блоктарды қосымша қайта өңдеуден тұрады. Жерасты шаймалау технологиясы уран кен орындары үшін жақсы игерілген. Ілеспе компоненттерді жерасты шаймалау технологиясы пайдаланылатын реагенттер, аппаратуралық ресімдеу және т.б. бойынша ғана ерекшеленеді, бірақ олар өндіру тәсілі бойынша ұқсас. Уран құмдарында ілеспе компоненттер ≤ 1 г/т-нан 0,1 г/т дейін болған жағдайда да, өндіріс тиімді болуы мүмкін. Осыған байланысты уран кен орындарының өңделген блоктарының дайын инфрақұрылымын пайдалану болашақта жақсы экономикалық тиімділікті күтуге мүмкіндік береді.

Түйін сөздер: уран кеніштері, ілеспе бағалы металдар, ілеспе пайдалы компоненттер, жер асты ұңғылап шаймалау, өнімді ерітінді.

Диверсификация уранового производства с целью добычи попутных ценных металлов

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Аннотация. Работа нацелена на диверсификацию производства за счет извлечения попутных ценных металлов на урановых рудниках. Особенность проводимой работы состоит в дополнительной переработке отработанных и действующих блоков с использованием существующей производственной инфраструктуры для добычи попутных полезных компонентов. Технология подземного выщелачивания хорошо отработана для урановых месторождений. Технология подземного выщелачивания попутных компонентов отличается только по используемым реагентам, аппаратурному оформлению и т.д., но они принципиально схожи по способу добычи. Даже при наличии в ураноносных песках попутных компонентов с содержанием ≤ 1 г/т, вплоть до 0,1 г/т производство может быть рентабельно. В связи с чем использование готовой инфраструктуры отработанных блоков урановых месторождении позволяет ожидать хорошую экономическую рентабельность в перспективе.

Ключевые слова: урановые рудники, попутные ценные металлы, попутные полезные компоненты, подземное скважинное выщелачивание, продуктивный раствор.

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