Код МРНТИ 52.13.19

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INCREASE IN FLOW RATE OF EXTRACTION WELLS DURING URANIUM LEACHING USING A CHEMICAL REAGENT

Abstract. The article presents the results of the study and analysis of the mining and geological features of the object of study, which made it possible to identify the main reason for the decrease in the flow rate of pumping wells due to the colmatation of filters and the filter part of wells due to the predominance of silicon compounds in the array. Therefore, the technology of decolmatization of filters and the filter part of wells is proposed and the results of pilot work to increase the flow rate of pumping wells during underground borehole leaching of uranium using ammonium bifluoride are presented. Comparative results before and after treatment of the leaching solution with ammonium bifluoride showed that the flow rate of various pumping wells increased from 1.4 to 4.4 m^3/h, and in others – from 2 to 5.3 m^3/h.

Key words: *colmatisation of filters, uranium, underground well leaching, flow rate, extraction well, ammonium bifluoride, hydrofluoric acid.*

Химиялық реагентті қолдана отырып уранды сілтілеу кезінде айдау ұңғымаларының дебитін арттыру

Андатпа. Мақалада зерттеу объектісінің тау-кен геологиялық ерекшеліктерін зерттеу және талдау нәтижелері келтірілген, бұл массивте кремний қосылысының басым болуына байланысты сүзгілер мен ұңғымалардың сүзгі бөлігінің колматациясына байланысты сорғы ұңғымаларының дебитінің төмендеуінің негізгі себебін анықтауға мүмкіндік берді. Сондықтан сүзгілерді және ұңғымалардың сүзгі бөлігін декольматациялау технологиясы ұсынылды және аммоний бифторидін қолдана отырып, уранды жерасты ұңғымасымен шаймалау кезінде сорғы ұңғымаларының дебитін арттыру бойынша тәжірибелік-өнеркәсіптік жұмыстардың нәтижелері келтірілген. Бифторидті аммониймен шаймалау ерітіндісін өңдеуге дейінгі және кейінгі салыстырмалы нәтижелер әртүрлі сорғы ұңғымаларының дебиті сағатына 1,4-тен 4,4 м^3 дейін, ал басқаларында сағатына 2-ден 5,3 м^3 дейін өскенін көрсетті.

Түйінді сөздер: *сүзгілерді колматациялау, уран, жерасты ұңғымаларын шаймалау, дебит, сорғы ұңғымасы, аммоний бифториді, фтор қышқылы.*

Повышение дебита откачных скважин при выщелачивании урана с применением химического реагента

Аннотация. В статье приведены результаты изучения и анализа горно-геологических особенностей объекта исследования, что позволило выявить основную причину снижения дебита откачных скважин из-за кольматации фильтров и прифильтровой части скважин за счет преобладания в массиве соединении кремния. Поэтому предложена технология декольматации фильтров и прифильтровой части скважин и приведены результаты опытно-промышленных работ по повышению дебита откачных скважин при подземном скважинном выщелачивании урана с применением бифторида аммония. Сравнительные результаты до и после обработки выщелачивающим раствором бифторид аммонием показали, что дебит различных откачных скважин увеличились с 1,4 до 4,4 м^3/ч, а в других – с 2 до 5,3 м^3/ч.

Ключевые слова: *кольматация фильтров, уран, подземное скважинное выщелачивание, дебит, откачная скважина, бифторид аммония, плавиковая кислота.*

Introduction

In terms of mineral reserves the Republic of Kazakhstan ranks second in the world among the uranium-producing states, it's estimated at 1,5 million tons. Therefore the country can almost unlimitedly increase cheap uranium production, along with Canada and Australia [1].

According to the moderate scenario of development of the world nuclear energy, uranium reactor needs will increase to 109 thousand tons by 2030 [2]. Uranium price is predicted to rise in the world because of the introduction of new nuclear reactors [3]. Today Kazakhstan makes the greatest contribution to uranium mining, ranking number one in the world. This fact was descended due to the use of underground in-situ leaching (ISL) technology [4]. About 70% of uranium reserves in Kazakhstan are suitable for processing in this way.

The main requirement for technological wells in ISL is a long period of exploitation (from 1-2 to 3-5 years) at conservation their productivity. Increase the efficiency of working out ore blocks can be achieved by managing the flow rate of technological wells [5, 6].

One of the main reasons for reducing the flow rate during underground well leaching is the colmatisation of filters and filtered aquifer zones. It provokes an increase in hydraulic resistance and a decrease in the flow of mortar into the wells.

Colmatation (from Italian colmata-filling, embankment) is the process of reducing natural penetration or artificial introduction of small (colloidal, clay and dusty) particles and microorganisms into rock pores and cracks, as well as deposition of chemicals in them, which contributes to reducing their water permeability, which in turn negatively affects the effectiveness of ISL [7].

A lot of efforts have been made to eliminate coltation processes in the filter zone, but in practice this problem has not been solved till now. Hence, it is very important to develop tools that can ensure fast and effective recovery of technological well flow rate.

Therefore, the purpose of this work is to restore the flow rate of extraction wells by finding effective methods to prevent colmatisation.

Research methods

Study and analysis of geological features, chemical composition of ore and rock, causes of colmation at the research site. During the pilot work, in order to avoid the loss of hydrogen fluoride during the reaction to the mouth of the casing column of the well, a loading box was installed and ammonium bifluoride was poured through it. Then, lowering the drain hose into the casing string to a depth below the static level of 5-10 m and fixing it at the mouth of the well, sulphuric acid solution was fed. The rate of the reagent supply to the well was regulated by the drain valve depending on its injectivity. The required supply volume of ammonium bifluoride and sulphuric acid solution to the well was determined taking into account the individual characteristics of the latter. After the supply of required quantity of mortar to the well, the drain valve was closed, the drain hose was removed from the well. Then a leaching solution (up to 5 m^3/h) was then applied to the well under pressure for 36 hours.

In conclusion, the filter zone of the well and settling tank were pumped up until the solutions were clarified.

Discussion of the results

The main reason for the decrease in the productivity of extraction wells is mechanical and chemical colmatisation of their filters and filter zone. Usually formation sand and products of chemical compounds are colmatising substances. The filter is filled with mechanical suspensions during the entire period of well operation. Part of the suspension is extraction out together with the productive solution, and the part, consisting of larger particles, settles and accumulates in the stand, and then in the filter zone [8, 9].

In most cases, sediments, colmatising filters and filter zones are multicomponent and at the same time may contain iron, manganese and hydroxides, calcium or magnesium carbonates, silica and sulphide compounds, as well as sand and clay. They are deposited on the surface of filters and in the pores of adjacent rocks under the influence of gravity or adsorbed under surface tension. Pumping of technological wells with compressed air and swapping are successfully used to combat mechanical colmatisation [10].

When chemical colmation is formed, the gradient of pH values in the permeable ore-bearing rock changes during the movement of leaching solutions from the injection well to the extraction well. As the pH value increases, the solutions are saturated with some salts that were simultaneously dissolved by sulphuric acid. Treatment of the filter zone of the technological well with solutions of different acidity is used to combat chemical colmatation. Resulting in partial or complete dissolution of salted compounds in the interpore space of ore-containing rocks. As a result of which the pore section increases and the productivity (debit) of the wells is restored. But, in addition to the loss of salts, which are relatively easily dissolved by sulphuric acid, there is a loss of dissolved amorphous silica in the interpore space of colloidal systems.

The object of this study is the Semizbay uranium field, located northeast of Stepnogorsk on the territory of the Enbekshilder district of Akmola region. It is timed to the north-eastern outskirts of the Kazakh Highlands, which passes into the West Siberian plain.

The mineral composition of the ores of the facility varies quite widely.

Ores and ore-bearing rocks by granulometric composition are sandy-clay, with low filtration coefficients. The yield of the size class (3 + 0) mm is 56.3-85.2%. A significant share of the ores is occupied by the aleuritic clay fraction – 22-45 %. The clay fraction contains less silicon (59-62%) and more aluminum (15-17%) compared to the entire ore. In chemical compositions, uranium ores are aluminous silicate, low-carbonate (less than 2% carbon dioxide), partially carbonated (organic substance less than 3%) and sulphide (sulphides less than 2% in total sulphur). The organic substance is quite widespread.

Its content in terms of Sorg varies from tenths to 5%, the substance is represented by carbonised plant residues (leaves, roots, stems, bark, trunks). Other sorbents are iron hydroxides (goethite, hydrohetite, hydrohematite) and sulphides: pyrite, markasite, less often bravoite, sphalerite, chalcopyrite, halenite.

The hydromica is most common clay mineral found in almost all types of ore-bearing rocks. Its content varies from 3-5 to 15-25% depending on the lithological type of rocks. Kaolinitis is found almost everywhere, but in relatively smaller quantities than hydromica. In the permeable part of the section, its number does not exceed 1-10%. The content of montmorillonite ranges from 0 to 10-15%, on average for individual sections (including clay-aluristic sediments) 6-7%.

Carbonates are an important part of cement. In permeable varieties, their content does not exceed 6-10%. The average CO_2 content in ores, calculated from samples with a total capacity of 2,739.4 metres, is 1.51%. The CO_2 content separately for aluminosilicate and carbonate ores was 1.02 and 7.96%, respectively. The bulk of carbonates is calcite and siderite, with ferrous dolomite and ankerite. Carbonates form inclusion in clay cement, separately insulated curbs or poikilite cement (in intensively carbonated rocks), often completely replacing clay minerals.

Useful components in ore are represented by minerals easily soluble in sulphuric acid solutions, localised among the bulk of insoluble and insoluble minerals. Uranium minerals are found in clay and carbonate cement, in organic matter and in association with iron minerals – pyrite, markasite, iron hydroxides. In addition to these ore components, soluble minerals include carbonates (calcite, dolomite, siderite), layered alumine silicates (chlorite, montmorillonite, kaolinite). Crystalised silica compounds in the interpore space are insoluble compounds and actually act as cement-forming rock in permeable rocks.

Often, chemical treatment of process wells using high acidity solutions does not give a positive result of proper quality (the effect of increasing the flow rate is short-term or no complete or the increase in flow rate occurs slightly). These facts indicate that most of the colicating compounds are represented by silicon compounds.

It is known that hydrofluoric acid (hydrogen fluoride – HF) is the effective means of dissolving such compounds. Its action is based on the formation of a gaseous silicon tetra fluoride. But a solution of hydrofluoric acid is an extremely dangerous compound, so direct contact with it on the surface is extremely undesirable.

It seems more acceptable to form hydrofluoric acid directly in the well by mixing ammonium bifluoride (fluoric acid salt produced by the chemical industry) and sulphuric acid solution. The resulting chemical product acts as a reagent for dissolving insoluble silicon compounds in the filter zone of the process well. This method was tested at the Semizbay field and the mine of the same name.

The table presents the results of chemical treatment using ammonium bifluoride in 8 extraction wells. The waiting time after pouring the solution averaged 36 hours. Ammonium bifluoride consumption for processing one well was 25 kg.

As can be seen from the data presented in the table, after chemical treatment of wells using the tested method, the flow rates in some wells increased from 1.4 to 4.4 m^3/h, and in others– from 2 to 5.3 m^3/h, i.e. from 48% to 200%. The processing of the table data results in changes in the flow rate of process wells before and after processing ammonium bifluoride.

Table 1

Results of production well flow research

Кесте 1

Технологиялық ұңғымалардың дебиттерін зерттеу нәтижелері

Таблица 1

Результаты исследований дебитов технологических скважин

№	Well number	Type of well	Flow rate before processing with NH4F*HF, m^3/hour	Volume NH4F*HF, kilo	Waiting time, hour	Flow rate after processing with NH4F*HF, m^3/hour
1	18a-8-9	pumping	2,3	25	36	3,8
2	18a-6-4	pumping	2,9	25	36	4,3
3	51-14-1	pumping	1,7	25	36	4,0
4	52-28-3	pumping	2	25	36	5,3
5	50-7-7	pumping	1,4	25	36	4,4
6	51-12-5	pumping	3,1	25	36	5,3
7	51a-9-6	pumping	1,5	25	36	2,7
8	50-8-6	pumping	0,7	25	36	2,1

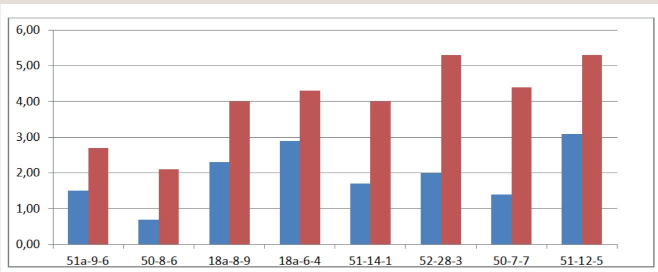

Figure. Change in flow rates of process wells

● – before processing;

● – after processing.

Сурет. Технологиялық ұңғымалардың дебиттерін өзгерту

● – өндеуге дейін;

●– өндеуден кейін.

Рисунок. Изменение дебитов технологических скважин

● – до обработки;

● – после обработки.

Conclusion

1. An effective way to develop hydrogenic uranium deposits is to use ISL technology. However, when using ISL, one of the main reasons for reducing the flow rate of wells is the colmatisation of filters and filter zones of the aquifer, which causes an increase in hydraulic resistance and a decrease in the flow of mortar into the wells.

2. There are various ways to combat colmatation. injection of technological wells with compressed air and swabation are used to combat mechanical colmatisation. The filter zone of the process well is treated with solutions with different acidity to combat chemical colmatisation. As a result, the dissolution of salted compounds in the pore space of ore-containing rocks occurs, the pore section increases, and the productivity (flow rate) of the wells is partially restored. However, these methods do not yield the desired results, so far a number of issues related to the development of methods and means of well recovery have not been resolved.

3. In terms of chemical composition, the uranium ores of the Semizbay are aluminosilicate, low-carbonate (less than 2% carbon dioxide), partially carbonated (organic substance less than 3%) and sulphidized (sulphides less than 2% in total sulphur), organic matter is quite widespread. Therefore, it was proposed to conduct research to eliminate colmatisation using ammonium bifluoride.

4. Studies in various process wells have shown that their flow rates after chemical treatment with ammonium bifluoride are increasing. With the latter's consumption of 25 kg, the flow rate increases from 48 to 200%

5. Ammonium bifluoride should not be mixed with other solutions, but poured into the well in dry form; after pouring the chemical reagent with acidic solution, hydrofluoric acid is formed directly in the filter zone, which dissolves insoluble silicon compounds, thereby reducing the colmation of process well filters.

Gratitude

These studies were carried out thanks to grant No. AP14871011 of the Committee on Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan.

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