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ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

NEWS

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN
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Қазақстан Республикасы Ұлттық ғылым академиясы "ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы" ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Web of Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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INNOVATIVE METHODS FOR INTENSIFYING BOREHOLE PRODUCTION OF URANIUM IN ORES WITH LOW FILTRATION CHARACTERISTICS

Abstract. The object of research is the technology of borehole uranium production with a low filtration characteristics.

The purpose of the work is to increase the efficiency of borehole uranium production in complex mining and geological conditions by developing a new method based on the intensification of geotechnological processes of underground leaching of uranium, the impact of chemical reagents on the aggregate of sedimentation and mineralogical composition of ore-containing rocks of the productive horizon. At the same time, operating costs are reduced by increasing the productivity of the period of uninterrupted operation of geotechnical wells, as well as reducing the time spent working out technological blocks.

Research methods include x-ray phase analysis, identification and discussion of the features, quantitative and qualitative parameters of core material and sedimentation from uranium deposits associated with the Syrdarya depression. Under laboratory conditions, the efficiency of the selected composition for the dissolution of sedimentary formations that reduce the permeability of layers was established by electron microdiffraction.

The applied hydrodynamic methods of well regeneration based on destruction and dispersion of sedimentation are considered and evaluated. The reagent methods used to increase the permeability of the productive horizon based on precipitation dissolution were also studied and evaluated. The results of experimental studies are analyzed and discussed, and a comparative schedule of the period of uninterrupted operation of wells is constructed. The effectiveness of the applied method for restoring the permeability of the productive horizon with the use of a complex chemical reagents.

The scientific novelty lies in the fact that mineralogical studies of the core material composition indicate a complex structure of ores, in complex mining and geological conditions. The practical significance of the study lies in the high efficiency and applicability of the considered method of intensifying borehole uranium production in areas with low filtration characteristics.

Key words: Microdiffraction, x-ray phase analysis, permeability, regeneration, leaching, uranium, sedimentation.

1. Introduction. Kazakhstan has 14 % of the world's proven uranium reserves and second ranks after Australia, 70 % of them are suitable for well development. Borehole development of uranium ores in the Republic of Kazakhstan is carried out at 26 sites, united in 13 uranium mining companies. The total volume of natural uranium production is more than 40% of the world's total. Uranium deposits are located in six provinces: Shu-Sarysu, Syrdarya, North Kazakhstan, Pre-Caspian, Pre-Balkhash, and Ile, the main production is carried out in the first two. The technology of borehole uranium mining provides for the dissolution of the useful component at the site of the ore body, followed by the removal of the formed compounds by a moving stream of solvent from the injection to the pumping well [1,2]. The practice of operating well systems in the development of uranium ores by borehole method shows that over time there

is a decrease in their productivity. One of the main reasons for reducing the throughput capacity of technological wells is an increase in hydraulic resistances and a decrease in reservoir filtration characteristics due to the formation of colmatation. [3].

Mechanical sedimentation is caused by overlapping of water intake filter holes with sand, clay, gravel and blockage of pore channels by the formation with solid suspensions. Sand and clay deposited in the well partially or completely covers the filter. Also, this type of precipitation can be attributed to the blockage of the filter and the near-filter zone by the formation with drilling fluids containing clay particles [4]. In this case, the clay material swells in the water environment and changes the structure of the pore space of the formation.

Chemical, ion exchange and gas types of sedimentation are caused by changes the chemical composition in reservoir waters as a result the influence of technological solutions used in mining. The presence of dissolved calcium, magnesium, and iron cationites in water and a violation of the carbon dioxide balance leads to the formation of insoluble precipitation [5]. There is an intensive release of carbonate precipitation in the filter zone, by removing it, the intensity of precipitation decreases.

2. Overview of applied methods for improving the filtration characteristics of ores. Depending on the type of sedimentation in the work areas of the geotechnological field, various methods of RRW (repair and restoration work) are used to improve the filtration characteristics of the productive. Hydrodynamic methods, such as compressor pumping and well flushing under the influence of pressure difference, are mainly aimed at destruction and dispersion of mechanical sedimentation [6]. The cost of these methods is relatively lower due to the use of technological equipment, inexpensive fuels and lubricants, etc. Chemical methods of exposure to dissolution are mainly aimed at destruction and elimination of precipitation formed as a result of the interaction of technological solutions with the host rocks of the productive horizon [7]. Combined methods include complex operations using drilling rigs and auxiliary equipment that combine well flushing with subsequent chemical treatment, swabbing, and compressor pumping [8]. This method is the most expensive due to the use of a large number of equipment, chemicals, maintenance personnel and a long duration of work.

2.1. Radiographic studies of host rocks. When leaching solutions interact with ore-containing rocks, the liquid phase accumulates (in addition to ore) a number of elements that are part of the main rock-forming minerals. The amount and kinetic transition of these elements to productive solutions depends on the type of leaching reagent, concentration, granulometric composition, and rock-forming minerals. Table 1 shows data on the mineralogical composition of ores from the Syrdarya Deposit.

Table 1 – Mineral composition of the Syrdarya Deposit

Mineral, mineral aggregate	Content, %
Quartz	65,7
Feldspar	8,6
Rock fragments	5,2
Carbonates	2,3
Montmorillonite	11
Muscovite	0,8
Fine-grained aggregate of silt-mica-clay composition, white, light gray color	1,6
Aggregate couplings with calcite, calcite	0,3
Iron sulfides	1,5
Carbonated organic matter	3,3

As can be seen from table 1, the most common clay mineral in the Syrdarya Deposit is montmorillonite, with an average content of 11% in some places. Feldspars are found everywhere, with an average content of 8.6%. The content of carbonates does not exceed 2.3 %. The main mass of carbonates is represented by calcite and ankerite.

X-ray studies of sedimentation. Solving problems with restoring the natural permeability of the productive horizon, first of all, it is necessary to determine the type of precipitation formed during sulfuric

acid leaching and establish the mineralogical composition of sedimentation. The study of quantitative and qualitative characteristics of sedimentary components will allow us to determine the reasons that reduce the permeability of filtration characteristics, which increase the productivity and duration of uninterrupted operation of geotechnical wells. The results of quantitative mineralogical composition of sedimentary formations of the Syrdarya province are shown in table 2.

Table 2 – Mineralogical composition of sedimentation in the Syrdarya depression

The component name	Chemical formula	Content, %
Quartz	SiO ₂	2
Aluminium phosphate	Al (PO ₄)	11
Iron oxide	Fe ₃ O ₄	14
Magnesium sulphate	MgS	11
Calcium aluminum hydroxide	CaAl ₂ ((O H) ₈ (H ₂ O) ₂)	1
Ankerite	Ca (Mg Fe Mn) (CO ₃) ₂	51
Dolomite	Ca Mg Fe (CO ₃) ₂	6

2.2. Laboratory experiments on the selection of chemical reagents for RRW wells. To restore the permeability of the near-filter zone of the formation in order to increase the efficiency of borehole uranium production, the authors conducted work on the development of a complex of chemical reagents. The basis adopted one of the technologies of increasing the efficiency of wells used in oil and gas industry – specific acid treatment of ore-bearing rocks with a special solution for cleaning of the pore space and to create new channels of traffic solutions and enlarge the existing, and to well clearing [10].

Under laboratory conditions, the effectiveness of the selected chemical reagents on precipitation was studied. We consider the change in the equilibrium of the system and the transfer of insoluble compounds to the liquid phase, or to turn solid sedimentation into easily soluble compounds. A number of analytical and experimental studies were carried out on samples of sedimentation and ore-containing rocks to select the most effective solution. As additives to the sulfuric acid solution, ammonium bifluoride (NH₄HF₂) and surfactants were used to loosen sedimentation.

Reagents included in the multifunctional complex:

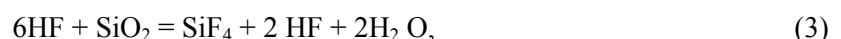
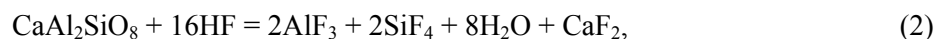
- Sulfamic acid;
- Ammonium lignosulfonate;
- Ammonium bifluoride.

The choice of ammonium bifluoride to influence precipitation is due to its ability to exchange reactions with mineral acids (sulfuric, hydrochloric, nitric acids). The formation of hydrofluoric acid occurs:



where – HAn (H₂SO₄; HCl; HNO₃).

Hydrofluoric acid, formed as a result of the reaction, easily interacts with aluminosilicates and siliceous compounds, which are a component of ore-containing rocks according to the formulas:



As a result, both the main sedimentation and part of the terrigenous component of the sands are dissolved. In general, the effective porosity of the ore block increases. In this case, hydrofluoric acid is completely utilized due to the large amount of quartz contained in the sands.

Microdiffraction images of the sedimentation surface before and after treatment with a solution and obtained information about the composition, structure and other properties of the surface layers confirm the effectiveness of the selected chemical reagents. Figures 1 and 2 show electronic microdiffraction of, selected sedimentation before and after treatment with special solutions

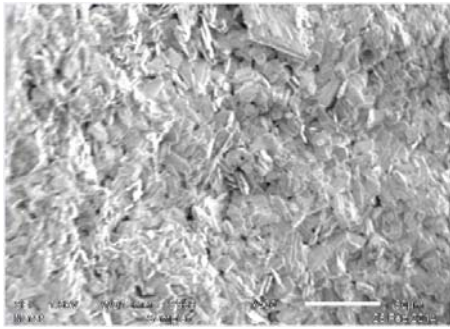


Figure 1 – The electronic microdiffraction selected colmatant before treatment.

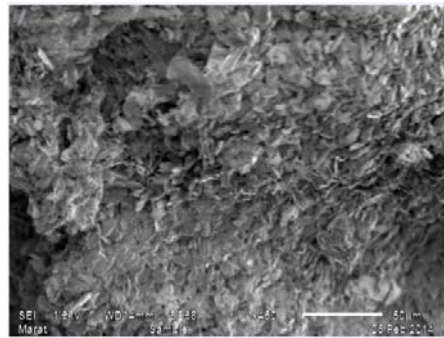
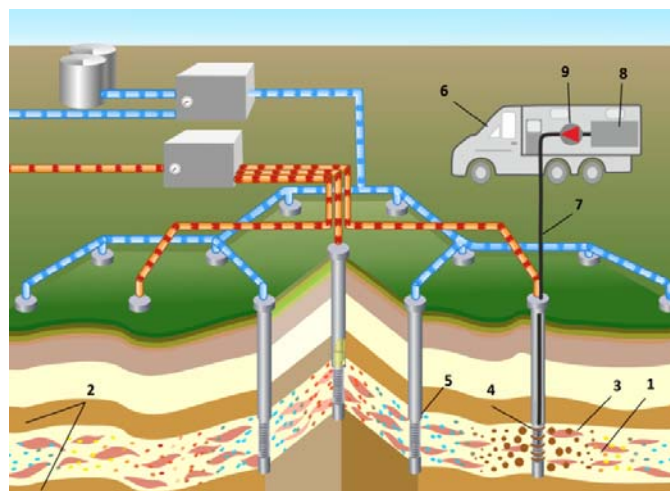


Figure 2 – The electronic microdiffraction selected colmatant after treatment.

As can be seen from the image (figure 2), precipitation before processing has a dense cellular structure with a rhombic frame structure, without breaks and cavities in the body. After processing this sample with a special solution, a second electron microscope image was taken (figure 2). From figure 2, you can see that the sample has flushed and additional space and cracks in the structure. The results of laboratory studies indicate the possibility of using ammonium bifluoride as an additive to a solution of sulfuric acid for effective chemical treatment of technological wells.

3. Development of intensification methods for uranium mining. To increase the efficiency of borehole uranium mining by improving geotechnological processes and restoring the permeability of the near-filter zone of the formation, the authors developed and tested a method for chemical treatment of wells with a special solution. This method of influence on the formation provides for the supply the solutions of complex chemical reagents to the filter zone, pressing into the productive horizon for its reaction with sedimentation, dissolution and removal of reaction products outside the well by airlift pumping. Figure 3 shows a scheme for the intensification of borehole uranium production.

As can be seen from figure 3, the main mass of sedimentation 3 occurs in the productive horizon 1, directly in the zone of unloading solutions and increasing the speed of movement of solutions from injection wells 5 to pumping wells 4. Chemical treatment with the use of complex chemical reagents provides for the preparation of solutions on special equipment 6, and supply through the hose 7 to the filter part of wells 4. In this case, the prepared special solution is fed from the tank capacity 8, by a pumping pump 9. The supply of a complex of chemical reagents directly to the filter part of technological wells reduces the consumption of chemical reagents and increases the penetration capacity for greater destruction and dispersion of precipitation.



1 – productive horizon; 2 – impenetrable rocks; 3 – sedimentation; 4 – pumping wells; 5 – injection wells; 6 – special equipment for the preparation of solutions ; 7 – hose; 8 – tank; 9 – pumping pump.

Figure 3 – Scheme for the intensification of borehole uranium production

Conclusions. Features of uranium production in the fields of Kazakhstan are considered. The mineralogical composition study of host rocks samples confirms the high presence of carbonate minerals-ankerite > 2.3 %, the presence of montmorillonite clay > 11 % of the total weight of the core sample. Data from x-ray phase analysis of sedimentation confirm the precipitation of carbonate compounds that make up > 51 % of the total mass of sedimentation that belong to the chemical type of sedimentation. These sedimentary formations interfere with current lines and hinder the processes of borehole uranium mining, and increase operating costs for restoring the permeability of the productive horizon.

In order to develop an effective method for intensifying uranium production, laboratory studies were conducted and special chemical reagents were selected that can dissolve and prevent sedimentation. The effectiveness of chemical reagents in the destruction and dispersion of sedimentation during borehole uranium mining was confirmed by the method of electronic microdiffraction. A new method of geotechnical processes intensification was developed and experimental studies were performed using the developed complex of chemical reagents.

As a result of experimental work, the effectiveness of intensification with the use of complex chemical reagents was established. The duration of the uninterrupted operation of wells increased from 16 to 84 days, and the well utilization rate increased from 0.74 to 0.98. The use of a new method for intensifying borehole uranium production makes it possible to increase the efficiency of processing technological blocks in difficult geological conditions and reduces the material costs of operating blocks, increases the period of uninterrupted operation of geotechnical wells and reduces the cost of chemical reagents for repair and restoration work.

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ТӨМЕН СҮЗГІЛІК СИПАТТАМАСЫ БАР КЕНДЕ УРАН ӨНДІРУ ҰҢҒЫМАСЫН ҚАРҚЫНДАТУДЫҢ ИННОВАЦИЯЛЫҚ ӘДІСТЕРІ

Аннотация. Зерттеу объектісі – уранды ұңғымалық өндіру технологиясы.

Жұмыстың мақсаты – уранды жерасты геотехнологиялық процесін қарқындалуға негізделген жаңа әдіс әзірлеу, химиялық реагенттердің шөгінді жиынтығына және өнімді горизонттың кен сыйымды жынысының минералогиялық құрамына әсер етуі есебінен күрделі тау-геологиялық жағдайында уранды ұңғымалық өндірудің тиімділігін арттыру. Бұл ретте геотехнологиялық ұңғымалардың үздіксіз жұмыс істеу кезеңінің өнімділігін арттыру, сондай-ақ технологиялық блоктардың жұмыс істеу уақытын қысқарту есебінен пайдалану шығынын азайтуға мүмкіндік туады.

Зерттеу әдістері рентгенофазалық талдау, Керн материалының сандық-сапалық параметрлерін және Сырдария депрессиясымен шектелген уран кен орындарынан шөгінді түзілім анықтау мен талқылауды қамтиды. Ұңғыманы декольматациялау және күрделі тау-кен геологиялық жағдайында уран тиімділігін арттыру үшін синергетикалық әсер ететін химиялық реагенттердің құрамы таңдалды. Зертханалық жағдайда электронды микродифракция әдісімен резервуардың өткізгіштігін төмендететін шөгінді ерігіштігі үшін таңдалған құрамның тиімділігі анықталды.

Зерттеу нәтижелері күкірт қышқылын еріткіш ретінде қолдана отырып, уран кенін ұңғымалық өндіруде жүретін процестерді зерттеу, сондай-ақ Қазақстан кен орнындағы күрделі тау-кен геологиялық жағдайда уран өндіру ұңғымасының геотехнологиялық параметрлерінің төмендеуіне әсер ететін себептерді қарастыру болып саналады. Бұзылу және диспергирленуге негізделген ұңғымаларды қалпына келтірудің гидродинамикалық әдістері қарастырылып, бағаланды. Кольматанттың еру үдерісіне негізделген өнімді горизонт өткізгіштігін жоғарылатудың қолданылатын реагенттік әдістері қарастырылды. Уранды ұңғымалық өндіруді қарқындалуда синергетикалық әсер ететін іріктелген химиялық реагенттерді қолдану бойынша әдістеме әзірленді және эксперименттер жүргізілді. Эксперименттік зерттеу нәтижелері талданып, талқыланды, ұңғымалардың үздіксіз жұмыс істеу кезеңінің салыстырмалы кестесі жасалды. Синергетикалық әсер ететін химиялық реагенттер кешенін қолдана отырып, өнімді горизонт өткізгіштігін қалпына келтіру әдісінің тиімділігі анықталды және көрсетілді.

Ғылыми жаңалығы Керн материалының құрамын минералогиялық зерттеу күрделі тау-кен геологиялық жағдайында тау жынысы мен уран минералдануын қамтитын кеннің күрделі құрылымын қамтиды, ал

түзілімінің белгіленген құрылымы мен сандық-сапалық параметрлері уран өндірудің күкірт қышқылды ұңғымасы жағдайында карбонатты және сазды минералдың тұнбаға түсетінін растайды. Зерттеудің практикалық маңыздылығы сүзгілеу сипаттамалары төмен учаскелерде уранды ұңғымалық өндіруді қарқындатудың қарастырылып отырған әдісінің жоғары тиімділігі мен қолданылуына негізделеді.

Түйін сөздер: микродифракция, рентгенофазалық талдау, өткізгіштік, регенерация, уран.

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ИННОВАЦИОННЫЕ МЕТОДЫ ИНТЕНСИФИКАЦИИ СКВАЖИНОЙ ДОБЫЧИ УРАНА В РУДАХ С НИЗКИМИ ФИЛЬТРАЦИОННЫМИ ХАРАКТЕРИСТИКАМИ

Аннотация. Объектом исследования является технология скважинной добычи урана на месторождениях с низкими фильтрационными характеристиками.

Цель работы – повышение эффективности скважинной добычи урана в сложных горно-геологических условиях за счет разработки нового метода, основанного на интенсификации геотехнологических процессов подземного выщелачивания урана, воздействия химических реагентов на совокупность осадкообразований и минералогического состава рудовмещающих пород продуктивного горизонта. При этом достигается снижение эксплуатационных затрат за счет повышения производительности периода бесперебойной работы геотехнологических скважин.

Методы исследований включают рентгенофазовые анализы, установление и обсуждение особенности, количественно-качественные параметры кернового материала и осадкообразований из месторождений урана приуроченных Сырдарьинской депрессии. Подобран состав химических реагентов синергетического действия для декольматации скважин и повышения эффективности выщелачивания урана в сложных горно-геологических условиях. В лабораторных условиях методом электронной микродифракции установлена эффективность выбранного состава по растворению осадкообразований, снижающих проницаемость пластов.

Результатами исследований являются изучение процессов, протекающих при скважинной добыче урановых руд с применением серной кислоты в качестве растворителя, а также рассмотрение причин, влияющих на снижение геотехнологических параметров скважинной добычи урана в сложных горно-геологических условиях на месторождениях Казахстана. Рассмотрены и оценены применяемые гидродинамические методы регенерации скважин, основанные на разрушении и диспергировании осадкообразований. Также изучены и оценены применяемые реагентные методы повышения проницаемости продуктивного горизонта, основанные на растворении осадков. Разработана методика и проведены экспериментальные опыты по применению подобранных химических реагентов синергетического действия при интенсификации скважинной добычи урана. Проанализированы и обсуждены результаты экспериментальных исследований, построен сравнительный график периода бесперебойной работы скважин. Определена и показана эффективность применяемого метода восстановления проницаемости продуктивного горизонта с применением комплекса химических реагентов.

Научная новизна заключается в том, что минералогические исследования состава кернового материала свидетельствует о сложной структуре руд, вмещающих пород и урановой минерализации в сложных горно-геологических условиях, а установленная структура и количественно-качественные параметры осадкообразований подтверждает выпадение в осадок карбонатных и глинистых минералов в условиях сернокислотной скважинной добычи урана. Практическая значимость исследования заключается в высокой эффективности и применимости рассматриваемого метода интенсификации скважинной добычи урана на участках с низкими фильтрационными характеристиками.

Ключевые слова: микродифракция, рентгенофазовый анализ, проницаемость, регенерация, выщелачивание, уран, осадкообразование.

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