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Satbayev University

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ИЗВЕСТИЯ

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SELECTION OF RATIONAL PARAMETERS FOR OPENING AND DRILLING OF TECHNOLOGICAL WELLS UNDERGROUND URANIUM LEACHING

Abstract. The object of research is the technology of opening and development of wells of underground uranium leaching.

The purpose of the work is to increase the efficiency of borehole uranium mining by developing rational drilling parameters and developing the near–well zone of the formation, depending on the hydrogeological characteristics of the productive horizon. At the same time, a reduction in the time for drilling and development of wells is achieved, an increase in labor productivity, technological equipment, as well as a reduction in material costs for restoration work.

The research methods include the development and justification of effective parameters for the opening of productive formations by the rotational method of drilling with backwash, depending on the properties of ores and characteristics of washing solutions at the uranium deposit of the Shu-Sarysu depression. The parameters of development are selected and discussed depending on the hydrogeological characteristics of productive formations for the preparation of geotechnological wells for operation.

The results of the research are the study of processes during the construction and development of geotechnological wells, the reasons for the decrease in filtration characteristics of ores of the productive horizon. The effective parameters of the opening of productive layers of underground uranium leaching with the use of a special drilling method have been calculated, which exclude the clogging of the productive horizon with drilling fluids at the stage of well construction. The possibility of reducing the time for borehole penetration and development by eliminating the impact of drilling mud and drilling products on the aquifer productive horizon is discussed. A method of selecting the depth of the pressure sleeve depending on the hydrogeological characteristics of the ores of the deposit has been developed.

The scientific novelty is expressed in the justification of the effective parameters of the opening and development of productive formations using rotary drilling with backwash, depending on the hydrogeological characteristics of ores.

The practical significance of the study lies in the high efficiency and applicability of the considered method of opening and developing the productive horizon in the construction of technological wells in areas with a high content of clay minerals and low filtration characteristics.

Key words: well construction, sinking, development, drilling mud, face, airlift, uranium, colmatation.

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УРАНДЫ ЖЕР АСТЫ СІЛТІСІЗДЕНДІРУДЕ ТЕХНОЛОГИЯЛЫҚ ҰҢҒЫМАЛАРДЫ АШУ ЖӘНЕ ИГЕРУ ҮШІН РАЦИОНАЛДЫ ПАРАМЕТРЛЕРДІ ТАҢДАУ

Аннотация. Зерттеу объектісі – уранды жерасты сілтісіздендіру үшін ұңғымаларды ашу және игеру технологиясы.

Жұмыстың мақсаты – өнімді қабаттың гидрогеологиялық ерекшеліктеріне байланысты бұрғылаудың ұтымды параметрлерін әзірлеу және ұңғыма маңындағы түзілу аймағын игеру арқылы уран ұңғымаларын өндірудің тиімділігін арттыру. Бұл ретте оқпанды суға түсіру және ұңғымаларды игеру уақытын қысқартуға, еңбек өнімділігін, технологиялық жабдықты арттыруға, сондай-ақ қалпына келтіру жұмыстарына материалдық шығындарды азайтуға қол жеткізеді.

Зерттеу әдістеріне Шу-Сарысу ойпатында уран кенорнындағы кен қасиеттері мен сілтісіздендіру ерітінділерінің сипаттамаларына байланысты кері жуу және айналмалы бұрғылау әдісімен өнімді қабаттарды

ашудың тиімді параметрлерін әзірлеу мен негіздеу кіреді. Геотехнологиялық ұңғымаларды жұмысқа дайындау үшін өнімді қабаттардың гидрогеологиялық сипаттамаларына байланысты игеру параметрлері таңдалып, талқыланды.

Зерттеу нәтижелері геотехнологиялық ұңғымаларды салу және игеру кезіндегі процестерді, өнімді қабаттағы кендердің сүзілу сипаттамаларының төмендеу себептерін зерттеу болып табылады. Арнайы бұрғылау әдісін қолдану арқылы жер асты уранды сілтісіздендірудің өнімді қабаттарын ашудың тиімді параметрлері ұңғымаларды салу сатысында өнімді қабаттың бұрғылау ерітінділерімен бітелуін есепке алмаған жағдайда есептеледі. Бұрғылау ерітіндісі мен бұрғылау өнімдерінің сулы қабатқа әсерін жою арқылы ұңғыма оқпанын бұрғылау және игеру уақытын қысқарту мүмкіндігі талқыланады. Кенорын кендерінің гидрогеологиялық сипаттамаларына байланысты қысымды шлангтың ену тереңдігін таңдау әдістемесі дайындалды.

Зерттеудің ғылыми жаңалығы кеннің гидрогеологиялық сипаттамаларына байланысты кері жуумен айналмалы бұрғылауды қолдану арқылы өнімді қабаттарды ашу және игерудің тиімді параметрлерін негіздеуден көрінеді.

Зерттеудің практикалық маңыздылығы сазды минералдар көп және сүзілу сипаттамалары төмен аудандарда технологиялық ұңғымаларды салу кезінде өнімді горизонтты ашу және игерудің қарастырылып отырған әдісінің жоғары тиімділігімен қолданылуында.

Түйін сөздер: ұңғымаларды салу, қазу, игеру, бұрғылау шламы, ұңғыма түбі, эрлифт, уран, бітелу.

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ПОДБОР РАЦИОНАЛЬНЫХ ПАРАМЕТРОВ ВСКРЫТИЯ И ОСВОЕНИЯ ТЕХНОЛОГИЧЕСКИХ СКВАЖИН ПОДЗЕМНОГО ВЫЩЕЛАЧИВАНИЯ УРАНА

Аннотация. Объектом исследования является технология вскрытия и освоения скважин подземного выщелачивания урана.

Цель работы – повышение эффективности скважинной добычи урана за счет разработки рациональных параметров бурения и освоения прискважинной зоны пласта в зависимости от гидрогеологических характеристик продуктивного горизонта. При этом достигается сокращение времени на проходку ствола и освоение скважин, повышение производительности труда, технологического оборудования, а также сокращение материальных затрат на восстановительные работы.

Методы исследования включают разработку и обоснование эффективных параметров вскрытия продуктивных пластов вращательным методом бурения с обратной промывкой в зависимости от свойств руд и характеристик промывочных растворов на месторождении урана Шу-Сарысуйской депрессии. Выбраны и обсуждены параметры освоения в зависимости от гидрогеологических характеристик продуктивных пластов для подготовки геотехнологических скважин к работе.

Результатами исследований является изучение процессов при сооружении и освоении геотехнологических скважин, причин снижения фильтрационных характеристик руд продуктивного горизонта. Рассчитаны эффективные параметры вскрытия продуктивных пластов подземного выщелачивания урана с применением специального метода бурения, исключающие засорение продуктивного горизонта буровыми растворами на этапе сооружения скважин. Обсуждена возможность сокращения времени на проходку ствола скважины и освоение за счет исключения воздействия бурового раствора и продуктов бурения на водоносный продуктивный горизонт. Разработана методика подбора глубины заглубления напорного рукава в зависимости от гидрогеологических характеристик руд месторождения.

Научная новизна выражается в обосновании эффективных параметров вскрытия и освоения продуктивных пластов с применением вращательного бурения с обратной промывкой в зависимости от гидрогеологических характеристик руд.

Практическая значимость исследования заключается в высокой эффективности и применимости рассматриваемого метода вскрытия и освоения продуктивного горизонта при сооружении технологических скважин на участках с высоким содержанием глинистых минералов и низкими фильтрационными характеристиками.

Ключевые слова: сооружение скважин, проходка, освоение, буровой шлам, забой, эрлифт, уран, кольматация.

Introduction. Uranium is the most representative element of the actinides, which is of fundamental importance in the nuclear fuel cycle. The downhole method of extracting uranium ores is the most common method of developing infiltration deposits. Compared to open-pit and underground mining, downhole field development is environmentally safe and cost - effective. Kazakhstan has 14% of the world's proven uranium reserves and ranks second after Australia (Figure 1). The development of deposits in the Republic of Kazakhstan is carried out by the well method at 26 sites united in 14 uranium mining companies (Rakishev, 2019: 9). The total volume of natural uranium production is more than 40% of the world's total (Figure 2) (Chen, 2018: 10).

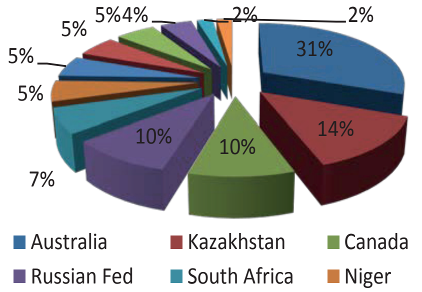

Figure 1 – Proven uranium reserves by country

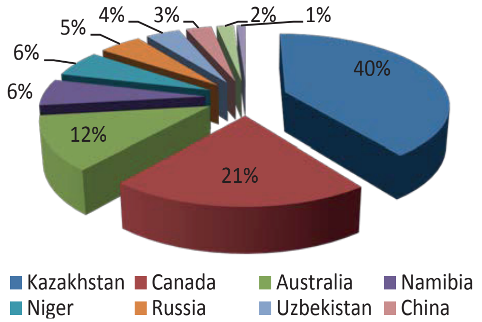

Figure 2 – Shared production countries of the world

The technology of borehole uranium production involves opening the ore horizon with technological wells, preparing the productive horizon for production, and then dissolving the useful component at the location of the ore body (Kenzhetaev, 2021: 7, Rakishev, 2020: 7). The construction of technological wells involves the use of a rotary drilling method with flushing, waterproofing of productive and aquifers with cement mortar and casing with production columns with subsequent development. The use of the rotary drilling method with direct flushing is due to the high productivity in soft rocks, the mobility of drilling equipment and the ability to conduct logging studies (Kassenov, 2020: 6, Kuandykov, 2020: 8). However, the opening of the ore horizon with the use of clay solution in ores with low filtration characteristics requires long-term development and causes the formation of impermeable areas that prevent the processes of well production.

The practice of operating geotechnical well systems in deposits with low filtration characteristics of ores shows that over time there is a decrease in their productivity. One of the main reasons for the decrease in the throughput capacity of technological wells is the formation of colmatation, due to the swelling of clay minerals, precipitation of substances dissolved in technological solutions, or mechanical movement of particles of the ore-containing horizon. Clay minerals that are not removed during the development of wells colmate the filters and near-filter zones of wells, increase hydraulic resistance and reduce the filtration characteristics of the productive horizon. They swell in the pores of adjacent aquifers under the action of sulfuric acid solutions or are adsorbed under the action of surface tension forces. Over time, the sediments are dewatered and compacted. The sediments have a loose-porous and conglomerate-like structure and at various stages of formation are characterized by different strength and reactivity. Reducing the filtration characteristics of ores negatively affects the processes of downhole production, increases labor costs, electricity, and increases the operating costs of production.

Research materials and methods. The selection of rational parameters for opening a productive reservoir and its development during the construction of technological wells will make it possible to obtain a high-performance and long-lasting technological well. The use of optimal parameters will significantly increase the efficiency of the well technology for uranium extraction in deposits with complex mining and geological conditions and ores with low filtration characteristics (Rakishev, 2019: 6, Polynovsky, 2012: 10).

The main condition for improving the efficiency of drilling operations is the use of such methods of opening and developing a productive reservoir, which ensure the preservation of the natural porosity and permeability of the host rocks or contribute to their increase in the bottom -hole zone of the well formation.

The use of a rotary drilling method with backwash is an important factor in improving the efficiency of reservoir opening and well productivity. In this drilling method, industrial water can be used as a flushing liquid, which enters the face through the gap between the well walls and the drill pipes, and the pulp formed during drilling rises to the surface through the drill pipes using airlifts or hydraulic elevators (ejectors) (Khawassek, 2016: 12, Rashad, 2020: 12, Atia, 2018: 11). The opening of productive formations with the use of back wash and water gives the greatest effect due to the preservation of the natural conditions of porosity and permeability of the host rocks (Mamytbekov, 2014, Panfilov, 2016: 13). Figure 3 shows the scheme of circulation of the washing solution during the opening of the productive horizon by the backwash method.

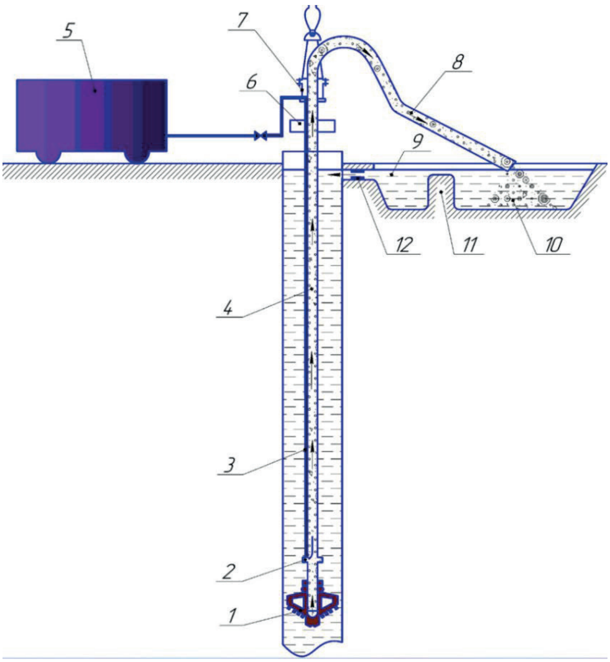

Figure 3. Backwash drilling scheme used to create airlift circulation
1-chisel; 2-mixer; 3-air pipes; 4-drill string; 5-compressor; 6-rotor;
7-swivel; 8-tube; 9-liquid tank; 10-drilling mud; 11-jumper;
12-chute for connecting the liquid tank with the well

With the method of drilling mud deposition from sludge, provide cleaning of drilling mud from drilled rock with a fraction with sizes of 0,3 mm or more. The cleaning process involves depositing suspended mechanical particles in a separate collection container, for further transportation and storage in a sludge collector. The total volume of solid particles removed must be at least 60% of the total volume of the drilled borehole.

With the rotary drilling method with backwash, it is planned to wash out the destroyed rocks from the bottom with a washing solution, which is fed at the required speed and density. Calculation of the flow rate of flushing fluid in drill pipes is determined by the formula:

$$V = \frac{4Q}{\pi d^2} \quad (1)$$

where; Q is the nominal capacity of the mud pump component - 4 l / s, d is the inner diameter of the drill pipes.

To lift the destroyed rocks from the face and carry them to the day surface through drill pipes, the washing solution must have an appropriate viscosity.

The effective viscosity for fluid flow through the pipe is determined by the formula:

$$\square_e = \frac{\tau * D_T}{8 * V} + \square \qquad (2)$$

where: τ is the dynamic stress of the washing solution, depends on the composition of the solutions, and η is the viscosity of the bentonite clay solution.

Defining the number Reynolds for the flushing solution flow through the drill pipe according to the formula:

$$Re = \frac{V * D * p}{\square_э} \qquad (3)$$

where: p is the density of the washing solution containing sludge.

The rate at which drilling mud is lifted from the face to the day surface depends on the pressure and volume of compressed air supplied to the mixer. The parameters of the airlift operation are regulated by the amount of displacement in the well to the height of the static level of the reservoir water from the surface. Depending on the hydrogeological characteristics of the deposit, the mixer immersion coefficient is determined by the formula:

$$k = \frac{H}{h} \qquad (4)$$

where H is the amount of immersion of the mixer at which there is a continuous outflow of reservoir water from the well. h – dynamic reservoir water level. In the fields of the Syrdarya depression, H is 40-60 m, and h is 20-40 m. In the areas of the Shu-Sarysui depression, H varies within 80-100 m., and h – 60-80 m.

With an increase in the depth of immersion of the mixer below the dynamic level of the liquid in the well, the efficiency is reduced airlift increases. The hydraulic efficiency of the airlift is determined by the formula:

$$\square = \frac{(k-1)^{0,85}}{1,05 * k} \qquad (5)$$

The air released from the mixer expands and, under the pressure of reservoir water, rises to the surface along the drill line, capturing the washing solution along with the drilling mud. This creates a rise and removal of drilling mud from the face to the day surface. The specific air flow rate V_0 required for lifting $1m^3$ of liquid from the well is determined by the formula:

$$V_0 = 10 * \square * \frac{\ln\left(\frac{H - h + 10}{10}\right)}{h} \qquad (6)$$

The flushing fluid allows you to clean the face of drilling mud and brings it to the daytime surface. The output of the required flushing fluid from the condition of complete removal of sludge from the bottom of the well is determined by the formula:

$$Q_r = \frac{\pi}{4}(D^2 - d^2) * V_n \qquad (7)$$

where Q_r is the flushing fluid flow rate, m^3/ s, D is the largest internal diameter of the well or casing pipes, m, d is the outer diameter of double drill pipes, m; 89 mm. v_n is the speed of the upward flow of the washing liquid in the annular space, m/s. When washing with clay solution ($v_п$=0,20,5). On direction is set at the wellhead, so the inner diameter of the well is 0.215 m.

The liquid column creates pressure at the level of the mixer, depending on the depth of its immersion in the well and the dynamic level of reservoir water. The necessary compressor design pressure is required to start the airlift and lift the drilling mud to the day surface (Pa) required to start the airlift in operation, which is determined by the formula:

$$P_s = \rho * g * h\left(1 + \frac{d_b^2}{D_n^2}\right) \qquad (8)$$

where: p - is the density of the working fluid, kg / $m^3$1060; g - is the acceleration of gravity, $m/s^2$9.80; h - is the geometric immersion of the mixer, m100; d_b - is the inner diameter of the air line, m 0.06; D_n - is the diameter of the lifting pipe, m 0.196 m.

The specific volume of air (м^3) required to lift the drilling mud (m^3) to the day surface depends on the density of the drilling mud and the immersion coefficient of the mixer and is determined by the formula:

$$q = \left(\frac{2}{k} - 1\right)\left(1 + \frac{\rho * g * h}{2\,P_a}\right) \qquad (9)$$

where: q – specific air flow, m^3/m^3; α – relative immersion of the mixer, 1.5; Pa - atmospheric pressure – 1 130 000 Pa.

The calculated parameters for injection of flushing fluid correspond to the penetration rate of 1.0-3.0 m / min, and the production rate of wells corresponds to the regulated data and is 15-20 m^3/h. The drilling of technological wells according to the calculated data allows you to increase the penetration rate by more than 20% and reduce the development time by 30 – 40%.

Discussion of the results. As a result of calculating the rational drilling parameters during the construction of technological wells, the speed of the flushing fluid in the well V - 3.9 – 4.0 m/s was determined at the uranium deposit of the Shu–Sarysu depression. The effective viscosity of the flushing fluid is - 20 * 10 $^{-3}$. The Reynolds number of the flushing solution flow in the well is 7214. The immersion coefficient of the mixer in the well is – 1.25 – 3.0. The air velocity during drilling is V_0 – 0.03 m^3/s. The estimated flow rate of the washing liquid Q_r is 0.006 m^3/s. The specific air consumption during drilling is q – 1.8 m^3.

Assessment of the operation of technological wells is carried out before commissioning according to development data and throughout the entire development period by productivity, injectivity and their period of uninterrupted operation, as well as by utilization factor. The data allow us to analyze the advantages and disadvantages of a particular method of opening and developing technological wells, as well as the quality of approaches used to restore the filtration characteristics of ores of a productive horizon.

Development of technological wells constructed by rotary drilling with backwash is the most efficient and cost-effective method of airlift pumping (Yusupov, 2017: 4, Zammit, 2014: 9). This is due to the absence of polluting components in the filter zone since the flushing solution is supplied through the borehole and the drilling mud is removed through drilling pipes. This makes it possible to reduce the development time of technological wells, increase their productivity and injectivity, and reduce operating costs for production. Figure 4 shows the scheme of development of technological wells by airlift pumping.

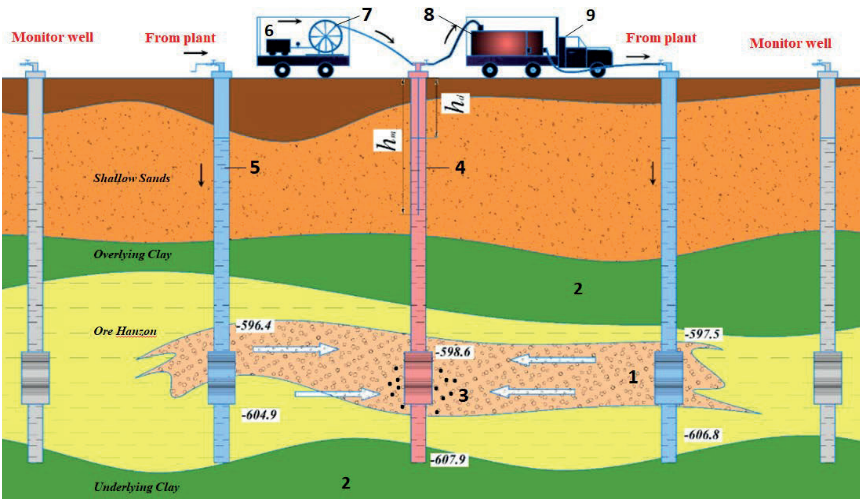

Figure 4. Scheme of development of technological wells
1 – productive horizon; 2 – impenetrable rocks; 3-sedimentation in the pre-filter zone of the formation; 4 – pumping wells; 5 – injection well; 6-compressor; 7 – winch with pressure tube; 8 – tank; 9-transport

Well treatment involves injecting compressed air into the well through a pressure tube, where it expands when released and lifts the solution from the well to the day surface. At the same time, the liquid level in the well decreases, which causes an influx of fluids through the filter from the productive aquifer. The rising solution captures the colmatation products and drilling mud residues from the near-filter zone of wells and takes them to a special container where it is cleaned and transported to the processing complex via a special temporary pipeline. The depth of immersion of the pressure air hose from the compressor is calculated depending on the hydrogeological characteristics of the field and the dynamic level of reservoir water and is determined by the formula:

$$H = k * h_d \tag{10}$$

where: k is the immersion coefficient of the pressure tube in the well and depends on the hydrogeological characteristics of the field, determined by Table 1.

Table 1. Values of the immersion coefficient from the dynamic reservoir water level

h, m	15	15-30	30-60	60-90	90-120
k	3-2,5	2,5-2,2	2,2-2	2-1,8	1,8-1,6

In the fields of the Syrdarya depression, k is 2.0 - 2.2, and in the fields of the Shu-Sarysu depression, k takes values of 1.8-2.0. It should be noted that when $K<1.6$, the efficiency of the airlift is very low, and at $K>3$, the operation of the airlift unit (airlift + compressor) requires very significant energy consumption of the drive motor.

Conclusion. The parameters of the construction of technological wells using the rotary drilling method with backwash show a lower impact on the productive horizon with drilling mud, and the removal of drilling mud is more efficient, which allows not to pollute the productive horizon. Based on the research results, it was found that the use of this technology can increase the drilling speed by 20-30% and reduce the time for well development. The productivity and injectivity of process wells increased by 20% due to a reduction in the effect of colmatation, and the period of uninterrupted operation of them increased by 30%. This result in savings in mining time, increased labor productivity, and reduced downtime of process equipment during opening and extraction at process units.

The use of calculated data for the development of technological wells will increase the efficiency of restoring the filtration characteristics of a productive horizon in a variety of mining and geological conditions. The airlift method of impact can be successfully applied to well leaching of various hydrogeological conditions, as well as in complex geological formations with a high carbonate content of $CO2>2\%$ and the presence of a multitude of silty-clay interlayers with deep ore-bearing rocks and high reservoir pressure. Providing a high degree of regeneration of wells with colmating deposits of various strengths, complicating the process well leaching and repair and restoration works.

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