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Қ. И. Сәтпаев атындағы Қазақ ұлттық техникалық зерттеу университеті

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СЕРИЯ ГЕОЛОГИИ И ТЕХНИЧЕСКИХ НАУК



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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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**THE ANALYSIS OF MODERN TECHNOLOGY
AND TECHNIQUE APPLIED
IN THE COMPLETION OF GEOTECHNOLOGICAL WELLS
AND REMEDIAL WORKS IN THEM**

Abstract. The issues related to the current state of conducting remedial works to recover geotechnological wells that are operated to mine uranium ores by the technique of underground borehole leaching are considered in the article. The essence of this method is that a chemical reagent that dissolves the ore into the liquid phase is pumped through one well (pumping/injection), and through other wells (production) the solution is lifted to the surface. The production wells tend to lose their initial productivity with the operation, and the injected ones - the injectivity due to colmatation of the working zone in well screen. The causes and types of colmatation are discussed and the analysis of existing equipment and technology for remedial works has been made. On the basis of this analysis, the promising areas for improving technology and techniques for remedial works in geotechnological wells have been identified.

Key words: well, flow rate, recovery, remedial works, well screen, colmatation, well injectivity.

Introduction. At present, the economy of the Republic of Kazakhstan mainly depends on the extraction and export of hydrocarbon raw materials, but according to many studies the world's reserves of this type of raw materials are limited and their quantity is sufficient only for the next 40-50 years.

But on the other hand, many countries, such as France, Japan, the United States, Canada and others have switched to an alternative source of energy – nuclear energy. For example, in France and Japan 80% of electricity is generated from nuclear power plants.

At the same time, Kazakhstan is very rich in ores for the nuclear industry, but today they are not consumed inside the country and the extraction of this raw material is carried out mainly for the purpose of its export. Consumption of raw materials in the nuclear industry in the future in the Republic of Kazakhstan as an alternative to hydrocarbon raw materials is beyond doubt.

25% of the world uranium reserves are concentrated in Kazakhstan, and about 70% of them are suitable for extraction by the method of underground in-situ leaching (ISL). The program for the development of the nuclear industry, approved by the Government of the Republic of Kazakhstan, envisages a sharp increase in uranium production in Kazakhstan. The solution to this task is achievable with the introduction of advanced technology and technique of exploration and production, with the replacement and improvement of the existing fleet of equipment, tools and training highly qualified specialists.

Currently, one of the most widely used methods for developing uranium deposits is geotechnological methods incorporating boreholes, the essence of which lies in underground in-situ leaching of uranium ores, i.e. the useful component (uranium ore) is transferred to the liquid phase by dissolving it with chemical reagents and then lifting the metal-saturated solution to the surface. For this purpose, a chemical reagent is injected through the wells drilled from the surface into the mineral deposit, capable of transferring minerals to the soluble phase and then lifting to the surface through other wells [10, 11].

This method of mining uranium minerals has one of the greatest advantages, which lies in the fact that it provides extraction without direct contact of man with ore.

However, with the operation of geotechnological wells, production wells lose their productivity over time, and the injection wells – their injectivity. These wells are subjected to remedial works after a certain period. There are thousands of such wells in the uranium deposits of Southern Kazakhstan that require cleaning.

The technology and technique applied do not always provide high-quality cleaning and take up considerable time. Carrying out remedial works to restore the productivity and injectivity of wells with the least material costs and time is very urgent.

Before considering the modern technology of screen decontamination, let us consider the causes and types of colmatation.

Colmatation of the well screens causes an increase in hydraulic frictional pressure losses when fluid is pumped into the well and, as a result, reduces the productivity of the well.

There are three types of colmatation: mechanical, chemical and biological [6].

Mechanical colmatation is observed in mesh, slotted, block filters due to the discrepancy between the perforations of screen holes in the granulometric composition of the aquifer. As a result of such colmatation, the water intake holes of the screens are wedged or overlapped by sand, clay, and therefore the specific yield is reduced by 20-30%.

The clay filtration occurring in rotary drilling using drill mud should also be attributed to mechanical colmatation. Over time, the filter cake is densified by increasing the adsorption and molecular bonds between the clay particles, and removing it presents considerable complexity.

When installing the screen, it is necessary to tend to reduce its claying. To achieve this, it's necessary to lower the filter with the lower open end or with washing windows, place a cement plug above the screen that's further is drilled out after screen installation, to cover the screen with special compounds that are dissolved after its installation in the well. Reduction of mechanical colmatation is also facilitated by the creation around the screen of the correctly executed gravel dump.

Chemical colmatation is caused by a violation of the chemical composition of groundwater as a result of changes in hydrodynamic parameters of the filtration flow.

As the water pressure decreases, the solubility of gases (mainly CO₂) decreases, their release occurs and the carbon dioxide equilibrium is violated, according to the following reaction:



The presence of calcium and magnesium in water leads to the formation of sparingly soluble precipitates of CaCO₃ and MgCO₃. The most intensive is the release of carbonate sediments in the filter zone. In filters having large hydraulic resistance, pressure losses increase, which leads to a more active release of CO₂ from the water and an even greater increase in the amount of carbonate precipitation.

The covering of screens and screen zones by carbonate sediments occurs mainly in wells drilled in limestones and dolomites (1.10).

The most common colmatizing deposits are ferruginous sediments, which are released during the production of groundwater containing ferrous iron. The transition of iron from ferrous to oxide and precipitation occurs when soluble oxygen is present in the water. This is also facilitated by the release of CO₂ and an increase in the pH of the water due to a violation of the carbon dioxide equilibrium:



The iron oxide hydrate, which has a gelatinous appearance, is deposited on the surface of the screens and in the pore space of the screen zones of the formation. The intensity of deposition of ferruginous sediments increases with the uneven production of water from the well, the use of an airlift or an ejector pump, which promote saturation of water with oxygen.

Violation of the chemical composition of groundwater in the producing layer can occur when interacting with the waters of other aquifers with insufficient capacity of the separating water retainer or the absence of cementation of the annular space. When mixing soft and hard waters, the concentration of carbon dioxide can increase, which causes the formation of carbonate sediments.

The covering of screens is greatly influenced by the presence in the groundwater of hydrogen sulfide H_2S . The content of HS hydrogensulfites leads to the formation of hardly soluble and impermeable sulfur deposits of iron, copper, zinc as a result of the reaction of groundwater with the filter framework material. Sulphides of metals in the form of cortical outgrowths of black color form a strong film coating on grids, wire windings, filter cages and contribute to their gradual destruction. It should be noted that sulphurous deposits are not deposited in the screen zones of the formation.

In the presence of silicic acid in iron-containing groundwater, the formation of sparingly soluble silicate deposits with an admixture of ferrous iron is observed.

Preventing the chemical colmatation when using waters with unstable chemical composition is impossible, since its cause is a violation of the natural drive of the aquifer.

To reduce the intensity of colmatation, one should not allow uneven operation of wells, do not use water lifts, during which the aerated water enters the filter zone.

In addition to precipitation, accumulation of deposits can occur as a result of corrosion of the screen itself due to the aggressiveness of underground water with the property of an electrolyte.

Electrochemical corrosion is more susceptible to screen filters, representing a steel perforated pipe, wound with a steel or copper wire mesh. These processes are greatly weakened in the manufacture of screens from plastics, the use of a screen mesh of stainless steel, the use of cords of polymeric materials instead of winding wires.

Biological colmatation is caused by the vital activity of microorganisms. The most active bacteria multiply in screens, where precipitation is formed under the influence of chemical or electrochemical processes. As a result of the life of bacteria (iron bacteria), iron hydroxide is liberated, which facilitates the transfer of ferrous oxide to insoluble oxide deposited on the working surface of the screens. The manganese bacteria present in the groundwater use the oxidation energy of the nitrous compounds and are transferred from the poorly soluble oxide compounds. Intensive biological colmatation is typical for groundwater with an oxygen content of 5 mg / l or more, which are located in the first aquifers from the surface of the earth. Bacteria are also found at great depths in zones far removed from watercourses and reservoirs.

Favorable conditions for the development of iron bacteria are found in most hydrogeological regions, therefore, in order to suppress their vital activity, it is necessary to periodically chlorinate the wells.

As a result of the analysis of a large number of literature sources, it was established [2] that the reasons for failure are (by the specific gravity of each of the following factors): filter collation - 40.9%; siltation and sanding of the well 37.77%, wear of pumping equipment - 12.52%; other reasons - 8.81%. Thus, the developed funds should be directed to the periodic decolmatation of screens and the fight against sanding and siltation of the well (together, these reasons amounted to 78%).

Therefore, depending on the type of colmatation, there are various ways of decolmatizing screens and productive horizons. These include circulating wellbores (through the washing window, with the help of packers and hydro-suckers, hydro- and pneumopulse, electric pulse, chemical, using explosives, etc.). The essence of these methods is described in some detail in various literary sources [1, 3, 9]. The analysis of the above-mentioned methods made it possible to determine their advantages and disadvantages. The disadvantages are:

- the complexity of the designs of technical products, which reduces their operational reliability;
- the overall dimensions of some technical devices do not always allow their descent into the screen column due to its small diameter, with which geotechnological wells are equipped;
- in carrying the chemical method of remedial works, certain safety measures are required when working with various types of chemicals, as well as the high cost of chemical reagents;
- with the electric pulse method of cleaning the screen surfaces, the disadvantages include the high cost of the equipment, observance of safety measures when working with high voltage;
- the use of explosive effect with the use of explosives in wells equipped with plastic screens can result in their destruction, the need for a special permit for blasting operations, as well as the high cost of explosives.

It should be noted here that the methods of conducting remedial works are similar to the methods of development at the stage of completion of wells.

Of greatest interest is the use of cavitated liquid for cleaning screens and the screen zone of the productive formation.

Cavitation [2, 4, 5, 7] (from Latin *cavita* - emptiness) - the process of vaporization and subsequent collapse of vapor bubbles with simultaneous condensation of vapor in the liquid flow, accompanied by noise and hydraulic shocks, the formation of cavities (cavitation bubbles, or caverns) filled with the vapor of the liquid itself. Cavitation occurs as a result of a local decrease in the pressure in the liquid, which can occur either with an increase in its velocity (hydrodynamic cavitation) or during the passage of an acoustic wave of high intensity during the half-life of rarefaction (acoustic cavitation), there are other causes of the effect. Moving with the flow into the area with a higher pressure or during the half-period of compression, the cavitation bubble collapses, while emitting a shock wave. The phenomenon of cavitation is of a local nature and arises only where there are conditions. It cannot move in the environment of origin. Cavitation destroys the surface of propellers, hydraulic turbines, acoustic radiators, shock absorber parts, hydraulic couplings, etc. Cavitation also benefits - it is used in industry, medicine, military equipment and other related fields. However, more recent studies have shown that the leading role in the formation of bubbles during cavitation is played by gases released into the emerging bubbles. These gases are always contained in the liquid, and when local pressure decreases, they begin to vigorously separate into the inside of these bubbles. Since under the influence of alternating local pressure the bubbles can contract and expand sharply, the temperature of the gas inside the vesicles varies widely, and can reach several hundred degrees in Celsius. There are computational data that the temperature inside the bubbles can reach 1500 °C. It should also be taken into account that the dissolved gases in the liquid contain more oxygen in percentage than in air, and therefore the gases in the bubbles are chemically more aggressive than the atmospheric air, resulting in the oxidation (reaction) of many normally inert materials. Cavitation is used for ultrasonic cleaning of surfaces of solids. Special devices create cavitation using sound waves in a liquid. Cavitation bubbles, collapsing, generate shock waves that destroy contaminant particles or separate them from the surface. Thus, the need for hazardous and unhealthy cleaning agents is reduced in many industrial and commercial processes where purification is required as a production step.

The number of cavitation. The cavitation flow is characterized by a dimensionless parameter (the number of cavitation) [2]:

$$K = \frac{P_0 - P_H}{\left(\frac{\rho v_0^2}{2}\right)} \quad (1)$$

where P_0 – hydrostatic pressure of the oncoming stream, Pa; P_H – pressure of saturated vapor of liquid at a certain ambient temperature, Pa; ρ is the density of the medium, kg/m³; v_0 is the flow velocity at the entrance into the system, m/s.

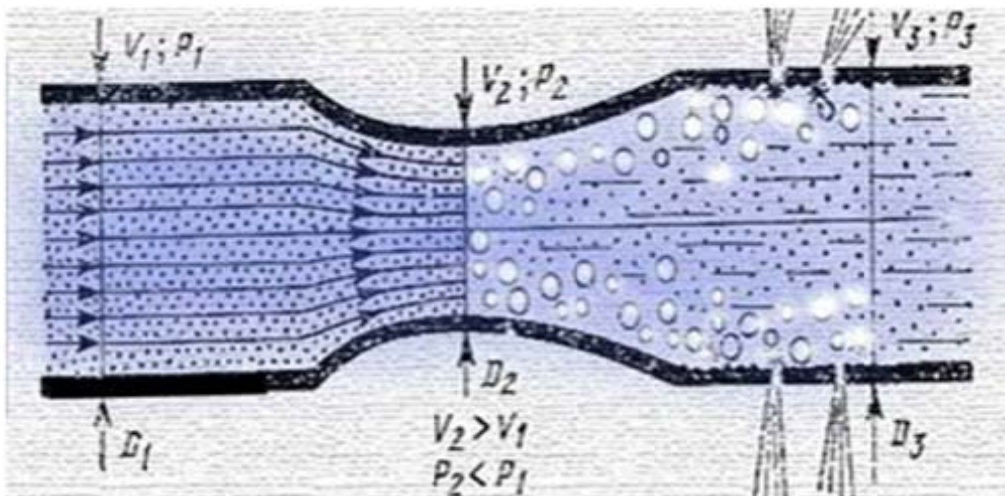


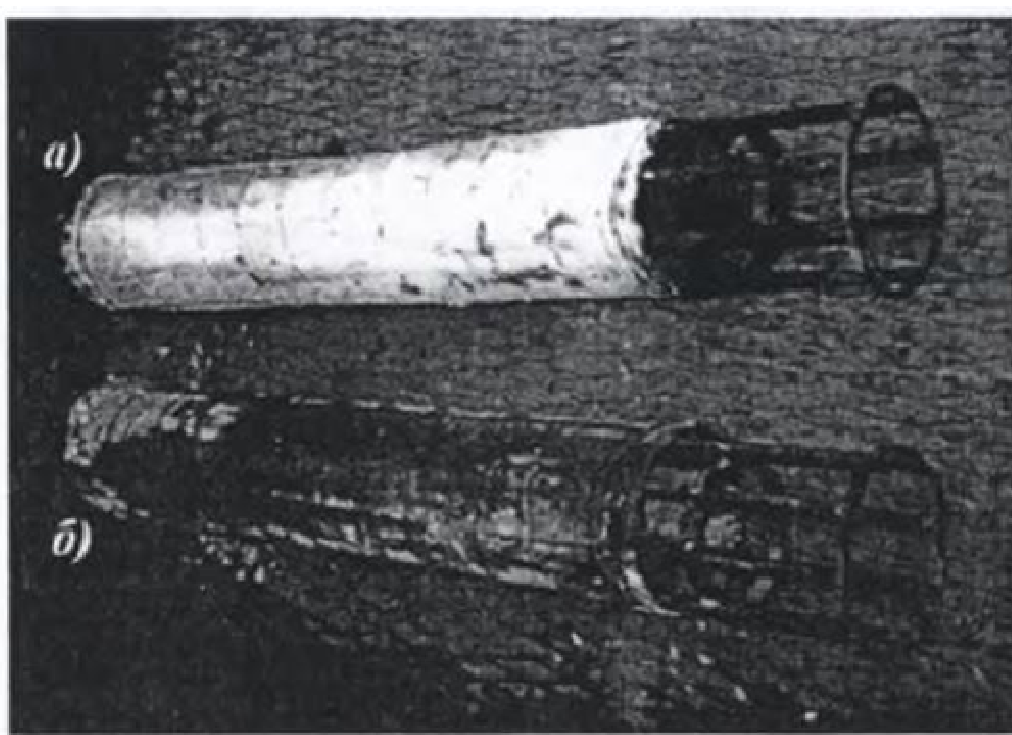
Diagram of formation of a cavitated liquid

The number of cavitation can take different values, but cavitation occurs only in the range $K = 0.1-0.6$. It is known that cavitation occurs when the flow reaches the boundary velocity, when the pressure in the stream becomes equal to the vapor pressure (saturated vapor). This speed corresponds to the boundary value of the criterion of cavitation.

Most often, cavitation is formed in the zone located on the pump's pressure line, in case of its narrowing i.e. the pressure of the liquid decreases after contraction (according to the Bernoulli law), since losses and kinetic energy increase. The saturated vapor pressure becomes greater than the internal pressure in the liquid with the formation of bubbles/caverns. After passing through a narrow part (it may be a slightly open gate, local constriction, etc.), the flow rate drops, the pressure increases and the bubbles of gases and vapors collapse. Moreover, the energy released in this case is very, very large, as a result of which (especially if it occurs in bubbles located on the walls) micro-hydro impacts occur that entail damage to the walls. At the same time, if you do not take measures, then the process will reach the complete destruction of the walls of the pump part. Vibration and increased noise in the pump and pipes are the first signs of cavitation.

The main weaknesses in the hydraulic systems are the places of narrowing, sudden changes in the flow velocity of the liquid (valves, cranes, latches) and impellers of pumps. They become more vulnerable when the roughness of the surface increases.

Serdyuk carried out large-scale studies on the use of cavitated liquid for decolmatation of screens and screen zones [2]. The experimental investigations carried out by the author were as follows. In the wells equipped with screens, the screens were cleaned with a conventional uncavitated fluid and another cavitated liquid. The appearance of filters obtained after treatment in cavitation and non-cavitation modes is presented in the photo (photo).



Appearance of the cavitatescreens after their treatment by the liquid flow in various modes:
a) uncavitated; b) cavitated

As can be seen from photo, the appearance of the screen, after its treatment in the cavity-free regime, has not changed, the thickness of the mud cake has remained the same. After treatment in cavitation mode for 15 minutes, the screen completely cleared of the mud cake. Visible in the photo, the remains of clay, in the author's opinion, are caused by contamination of the screen during its extraction.

Thus, the use of cavitated liquid for screen cleaning is a promising solution.

Conclusions. The analysis of methods and means of decolmatation of screens and aquifers, even with their positive effects, allows us to draw the following conclusions:

- the complexity of the designs of technical products, which reduces their operational reliability;
- the overall dimensions of some technical devices do not always allow their descent into the screen column due to its small diameter, with which geotechnological wells are equipped;
- in carrying the chemical method of remedial works, certain safety measures are required when working with various types of chemicals, as well as the high cost of chemical reagents;
- with the electric pulse method of cleaning the screen surfaces, the disadvantages include the high cost of the equipment, observance of safety measures when working with high voltage;
- the use of explosive effect with the use of explosives in wells equipped with plastic screens can result in their destruction, the need for a special permit for blasting operations, as well as the high cost of explosives.
- the use of cavitated liquid for screen cleaning is a promising solution and demands the improvement of the technology and technique used in conducting remedial and workover operations in geotechnological wells.

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ГЕОТЕХНОЛОГИЯЛЫҚ ҰҢҒЫЛАРДА ИГЕРУДІҢ ТЕХНОЛОГИЯСЫН, ТЕХНИКАСЫН ЖӘНЕ ЖӨНДЕУ-ҚАЛПЫНА КЕЛТІРУ ЖҰМЫСТАРЫН ЖҮРГІЗУДІ ЗАМАНАУИ ЗЕРТТЕУ

Аннотация. Мақалада уранрудаларын жер асты ұңғылық шәю әдісімен өндіретін геотехнологиялық ұңғыларды реанимациялау мақсатында жөндеу-қалпына келтіру жұмыстарын жүргізудің қазіргі жағдайының сұрақтары қарастырылған. Бұл әдістің мәні бір ұңғылардан (айдау) қабатқа руданы сұйылтатын химиялық реагент айдалады, ал басқа ұңғылардан (сору) ерітіндіні жер бетіне айдап шығарады. Пайдалану кезінде уақыт өте келе сору ұңғылары бастапқы өнімділігін жоғалтады, ал айдау ұңғылары сүзгілеу тізбегінің жұмыстық бөлігінің кольматациясы есебінен қабылдау қабілетін жоғалтады. Кольматация себептері және түрлері қарастырылды, сондай-ақ жөндеу-қалпына келтіру жұмыстарының қазіргі уақыттағы техникасы мен технологиясы сарапталды. Осы сараптаудың негізінде геотехнологиялық ұңғыларды жөндеу-қалпына келтіру жұмыстарының технологиясы мен техникасын жетілдірудің тиімді бағыттары анықталды.

Түйін сөздер: ұңғы, дебит, қалпына келтіру жұмыстары, сүзгілеу тізбегі, кольматация, қабылдау.

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**АНАЛИЗ СОВРЕМЕННОЙ ТЕХНОЛОГИИ,
ТЕХНИКИ ОСВОЕНИЯ И ПРОВЕДЕНИЯ
РЕМОНТНО-ВОССТАНОВИТЕЛЬНЫХ РАБОТ
В ГЕОТЕХНОЛОГИЧЕСКИХ СКВАЖИНАХ**

Аннотация. В статье рассматриваются вопросы современного состояния проведения ремонтно-восстановительных работ с целью реанимации геотехнологических скважин, которые эксплуатируются с целью добычи урановых руд методом подземного скважинного выщелачивания. Сущность данного способа заключается в том, что через одни скважины (закачные) закачивается в пласт химический реагент, растворяющий руду в жидкую фазу, а через другие скважины (откачные) откачивают раствор на поверхность. В процессе эксплуатации со временем откачные скважины теряют первоначальную производительность, а закачные – приемистость за счет кольматации рабочей части фильтровой колонны. Рассмотрены причины и виды кольматации, а также проведен анализ существующей техники и технологии проведения ремонтно-восстановительных работ. На основе этого анализа определены перспективные направления совершенствования технологии и техники проведения ремонтно-восстановительных работ геотехнологических скважин.

Ключевые слова: скважина, дебит, восстановление, ремонтно-восстановительные работы, фильтровая колонна, кольматация, приемистость.

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