**ABSTRACT**
**of the dissertation for the degree of Doctor of Philosophy (PhD) in the specialty 6D070700 - "Mining"**

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# IMPROVING THE EFFICIENCY OF VARIOUS IN-SITU LEACHING PATTERNS FOR COMPLEX HYDROGENOUS DEPOSITS DEVELOPMENT

**The assessment of scientific and technological problem current state**.

According to the IAEA, about 19% of all explored world reserves of uranium are concentrated in the depths of the Republic of Kazakhstan. The total reserves and resources are estimated at 1,610 thousand tons of uranium, including reserves of industrial categories (B + $C_1$ + $C_2$) estimated at 920 thousand tons.

A unique feature of the uranium reserves of the Republic of Kazakhstan is that 75% of them are concentrated in deposits associated with regional zones of reservoir oxidation. This type of deposits is not widely spread in the world and is being developed by the most advanced, relatively cheap and environmentally preferred method of in-situ leaching. In the in-situ leaching technology, also known as dissolution mining, the ore remains in a place of occurrence, and fluids are pumped through it to leach the minerals from the ore. Consequently, the soil cover remains almost undisturbed, waste rock is not formed.

The cost of production by the method of in-situ leaching is 2.5-3 times lower than the underground mines, so this method remains the most perspective.

The problem with the application of this technology is the decrease in the performance of technological wells. Generally, the reasons for the decrease in well productivity are colmation of filters and near-filter zones of the aquifer, the wrong choice of the well pattern, which cause an increase in hydraulic resistances and a decrease in the flow of the solution into the wells.

Currently, there are several ways to improve the performance of technological wells, such as elimination of colmation of filters, change in the drilling pattern and well location parameters. Moreover, some authors support row well patterns (5 spot), others support hexagonal patterns (7 spot). To date, there is no consensus on the benefits of a particular well pattern as well as on the technology of decolmation.

**The basis and initial data for the development of the topic**. The basis for the development of the thesis topic is the lack of a universal method for selecting the well pattern and parameters of technological wells, as well as the use of various reagents in mines without taking into account the geological conditions of the field being developed, ensuring a stable, uniform flow of the ISL process and rational consumption of reagents.

The mining and geological conditions of the Semizbay deposit, which is developed by the method of in-situ leaching, are selected as the initial data for the development of the research topic.

Justification of the need for research. The demand for uranium from year to year increases, and besides that, the demand and supply ratio of uranium in the world market for 2002-2015 years and the forecast up to 2025 shows that the world's shortage of uranium will be about 20 thousand tons. Despite this, a decrease in the price for the uranium is observed, so in 2010-2011 years, the cost of uranium was 110 dollars per kilogram and currently the price has dropped to 60 dollars per kilogram. Therefore, it is an urgent goal to increase efficiency and reduce the cost of uranium mining at existing enterprises. The solution to this problem is the scientific substantiation of the choice of a pattern of technological wells and their parameters, as well as the type of reagents in order to increase the interrepair time and increase metal recovery. Currently, the pattern and parameters of technological wells, reagents for decolmatting wells and increasing uranium extraction are taken by analogy, without taking into account the specific mining and geological conditions of the field being developed, the final decision is made after pilot tests

**Information about the planned scientific and technical level of development, patent research and conclusions from them** are determined by conducting a scientific analysis of the current state of the scientific and technical problem and patent research to improve the efficiency of in-situ leaching, in particular the choice of pattern and parameters of process wells, reagents for repair and enhance metal recovery. From the analysis, it can be concluded that the substantiation of these parameters as well as well pattern requires serious research. The thesis correctly used theoretical and experimental studies, collected a representative amount of statistical data, the mathematical processing of which showed the convergence of theoretical and experimental data.

**Information about the metrological support of the thesis.**

The thesis was carried out on the basis of pilot works at the Semizbay mine. The analysis of the research results was carried out on the basis of the chemical laboratory of the mine, the instruments and equipment of which have passed the state metrological calibration during the operation period.

In the tabular and graphical data, the units of measurement meet the metrological rules and standards of the International System of Units of SI.

**Relevance of the topic.**

An attractive aspect of uranium mining is the relative stability of the global uranium market demand. With an average lifetime of an energy reactor of 30-40 years, only the needs of the existing reactor fleet guarantee a certain level of global uranium demand for the next few decades. In this regard, investment risks in the uranium mining industry are significantly lower than in most mining industries. With the most unfavorable development of nuclear energy, by 2020, the demand of reactors will not fall below 60,000 tons of uranium. The probability of development in the baseline scenario is 65%. For the optimistic scenario, the probability of 20% and for the pessimistic 15%.

The choice of well pattern is made by analogy, the final decision is made after conducting pilot tests, which requires significant capital and operating costs. Depending on the mining and geological conditions of the field, the known methods of decolmation require additional research and often do not give the desired results. This problem is especially acute in the development of contiguous ore deposits.

The issues of increasing the efficiency of developing uranium deposits using the ISL method are the subject of research by a number of scientists. However, a number of points in them do not take into account the characteristics of specific deposits, especially those with contiguous deposits. Therefore, the solution of these issues is actual.

**The novelty of the topic** is to increase the efficiency of the ISL of uranium by selecting the pattern and parameters of the process wells depending on the pH value, determining the interrepair time of the wells and the uranium content in the pregnant solution from the volume of ammonium bifluoride and the use of hydrogen peroxide.

**Relationship of this work with other research projects.**

The dissertational work was performed in the framework of business agreement No. 281 dated December 23, 2016, “Development of technologies for reducing colmation frequency at ISL of uranium”.

**The goal of the research** is to increase the leaching efficiency of uranium based on rational patterns and parameters of the location of technological wells using various reagents.

**The object of research** is the Semizbay field, which is located northeast of Stepnogorsk, in the territory of the Birzhan district of the Akmola region and the Ualihanov district of the North Kazakhstan region.

**The subject of research** are the patterns and parameters of technological wells, repair and restoration works, the use of various reagents for ISL of uranium.

**The tasks of research, their place in the performance of research work in general:**

- study and analysis of the current state of uranium mining and restoration of well productivity at the object of study (chapter 1);

-the study of the effect of various patterns and parameters of the location of technological wells on the efficiency of ISL of uranium (chapters 2.3);

- study of the effect of various reagents on the intensification of the leaching process of uranium (chapter 4);

- development of recommendations for production (chapters 2,3,4)

The problems presented above and solved in this dissertation are logically interconnected and are aimed at achieving the goal of research.

**Methodological base of research**

The main research methods used in the design of the thesis include:

- analysis of the current state of scientific and technical problems and research to improve the efficiency of in-situ leaching;

- carrying out pilot works;

- collection and analysis of statistical data;

- processing of research results and development of recommendations for production.

**Provisions for defense**

The following provisions are to be defended by a thesis:

- the distance between the wells with different patterns must be determined taking into account the pH value, which will lead to a stable process of leaching and to the optimal time of the development of technological block;

- during the development of contiguous deposits, the productivity and the interrepair cycle of operation of technological wells depend on their pattern;

- the productivity of technological wells and the content of uranium in the pregnant solution depend on the concentration of ammonium bifluoride and hydrogen peroxide in solution.

**Publications and approbation of work**. The results of the work were reported at the international scientific and technical conferences: "Innovative development of the mining industry" (Kryvyi Rih, 2016) and "Scientific and personnel support of innovative development of the mining and metallurgical complex" (Almaty, 2017) as well as at the international conference "Satpayev readings "(Almaty, 2018) and "Modern scientific research: actual issues, achievements and innovations" (Penza, 2018), at scientific seminars of the department of "Mining" in the Kazakh National Research Technological University named after K.I. Satpayev.

Publications include two articles in the "Mining Journal of Kazakhstan", in the scientific and technical journal "University Proceedings" (Karaganda, 2018) and also in the rating journal "Mining Journal" (Scopus database), (Moscow, 2017).

**Structure and scope of work:** The thesis consists of an introduction, 4 chapters, conclusion, bibliographic list of 57 titles and contains 99 pages of typewritten text, 43 figures, 7 tables, 25 formulas.

## MAIN PART

Semizbay uranium deposit belongs to the group of hydrogenic deposits. The genesis of the deposit is reservoir-infiltrative. The deposit belongs to sandy-argillaceous group of deposits. Non-weathered deposits consist of uraninite, pyrite, and other sulphides that fill the pores in the rock formation and are usually in association with carbon, which is present in the form of wood or asphaltite material. Separate ore accumulations formed almost parallel and have a layer-like, almost elongated shape.

Semizbay field, by all direct and indirect features, belongs to the III hydrothermal type group of complexity. It is controlled by a deep-laid latitudinal fracture block with an amplitude of vertical movement of a granite block of up to 100 meters. There is a very weak sorting of the material, the fine-lined and thin-layered nature of the mineralized sands and clays, which greatly complicate and even preclude the reliable linking of lithological varieties in the cuts (at inter-well distance of 25 m). In addition, frequent abrupt transitions of ore sands into clays are associated with movements of lumps and fragments during tectonic activations, including the post-ore stage. According to geotechnological features, Semizbay field development using the ISL method is classified as the most complex. Ore bodies of the Semizbay deposit located within the depths of 60-130 m.

For ribbon-like, ore deposits elongated in the latitudinal direction, formed by balance ore bodies, characterized by a complex morphology and a sharply tortuous shape of ore lenses, industrial mining of geological blocks is carried out with a different patterns of wells. The most frequently used patterns are 25x25x30, 20x20x25, 25x25x25: “the distance between the pumping wells” X “the distance between the injection wells” X “the distance between the rows”. With a multitier (up to 3-4 tiers) arrangement of ore bodies, a row arrangement of wells is used in a manner similar to that indicated above. Distances between tiers up to 5m.

The following problems arose during the mining of this field: a non-optimal geochemical environment for uranium leaching, which leads to not maintaining the necessary pH values to minimize associated negative processes (for example, reducing the acidity along the streamline of solutions and the formation of colmation); non-optimal movement of technological solutions occurring due to the excess hydraulic pressure of the solutions in the places of multiplication of the injection wells at different levels.

Several variants of technological well location are used on the mine. Experimental work was carried out to select the technological wells effective patterns and parameters, taking into account the geological conditions. The main indicators for evaluating the effectiveness of the patterns were: well productivity and frequency of its colmation.

As the observations show, with a hexagonal well network, a decrease in the flow rate of seven out of nine wells is observed from 4% to 61%, and in two wells there was no colmation. In the remaining wells, the frequency of colmation is on average 2 times, sometimes 3 times with the duration of the overhaul cycle of their work up to 30 days. The figure 1 shows the of 4 wells, which showed the highest results after overhaul.

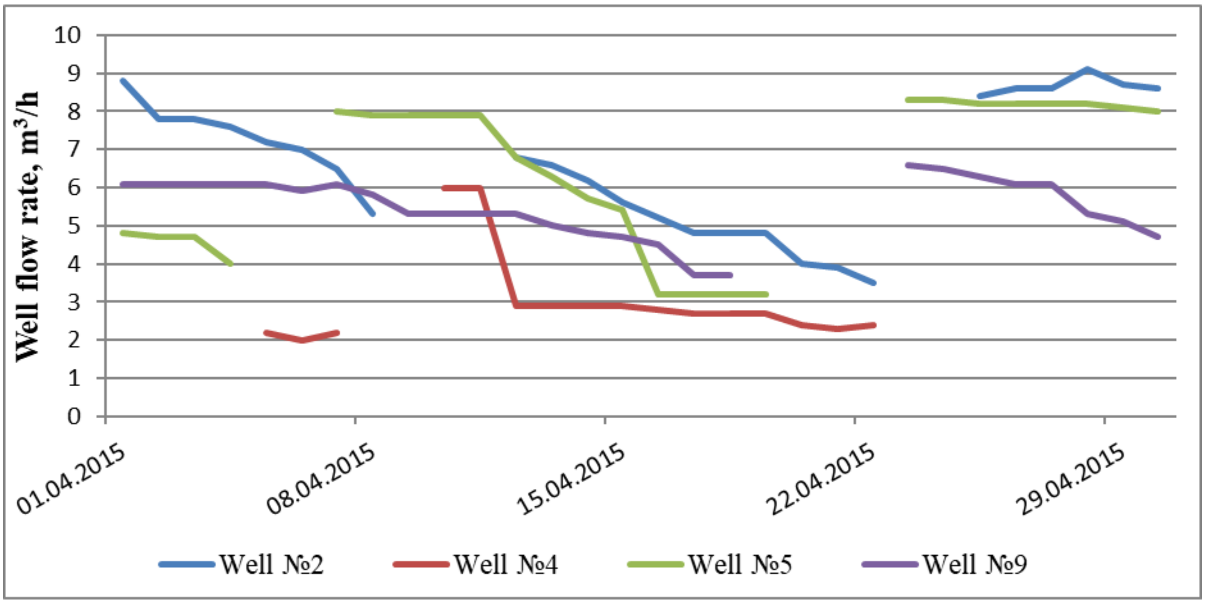



Figure 1 - Decrease in flow rate with a hexagonal well pattern

When using the row arrangement, a decrease in the flow rate of 2 wells for the same period (Figure 2) is observed to a maximum of 6%, and in six wells there was no work stoppage. The frequency of colmation on average is 1 time, with the duration of the overhaul cycle of their work of 30 days.

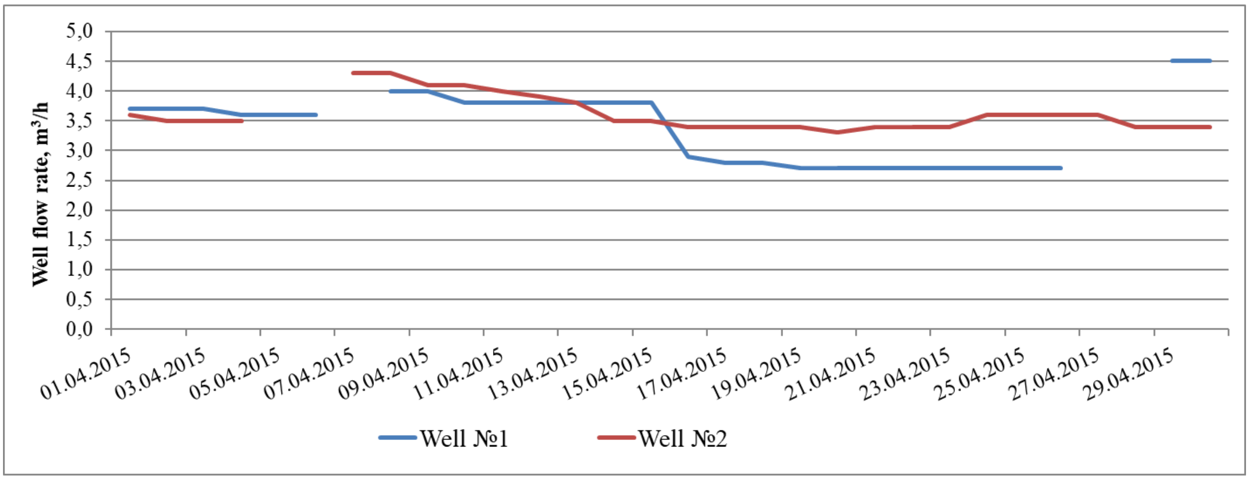
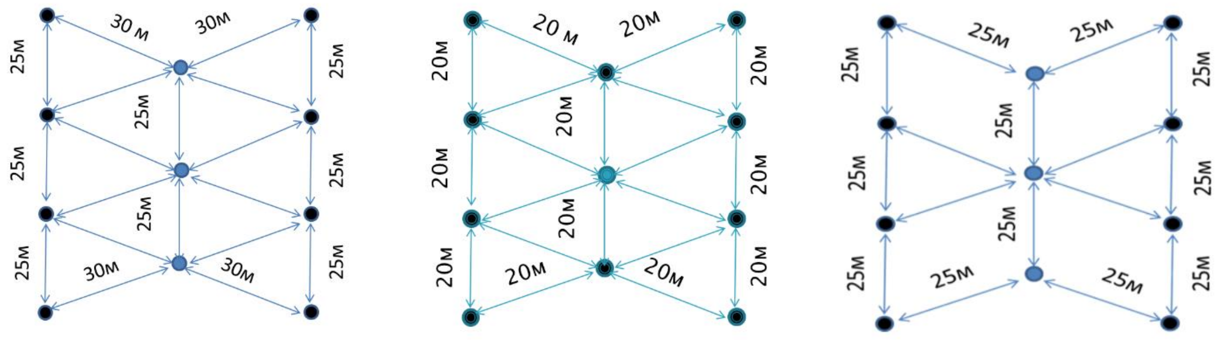



Figure 2 - Decrease in flow rate with the row arrangement of wells

As a result of the conducted research, it can be concluded that, under the mining and geological conditions of this field, the row arrangement of wells is effective from the view of maintaining the required flow rate and minimizing colmation frequency.

To determine the effective parameters of the drilling network with the selected row arrangement of wells, the parameters of technological wells used in this field were investigated (Figure 3).




a) b) c)

a) the arrangement of wells with a network of 25 * 25 * 30; b) the arrangement of wells with a network of 20 * 20 * 20; c) the arrangement of wells with a network of 25 * 25 * 25

Figure 3 - Existing well patterns

To determine changes in the pH of “pregnant” solutions on experimental-industrial blocks testing was carried out, as well as induction logging - in order to determine the time of passage of technological solutions between wells and the acidification zone. These indicators show the rate of acidification of technological blocks.

According to the results of the experimental work, the dependences of pH values on the network location of technological wells were obtained.

When the technological well arrangement network was 25x25x30 (Figure 4), it was found that the time required to undergo technological solutions to a pH value of 2.62 increased several times (over 100 days). At the same time, this value does not correspond to the optimal value of pH of the solution at which the leaching process takes place. The increase in the time of passage of the solutions leads to waste of used reagents.

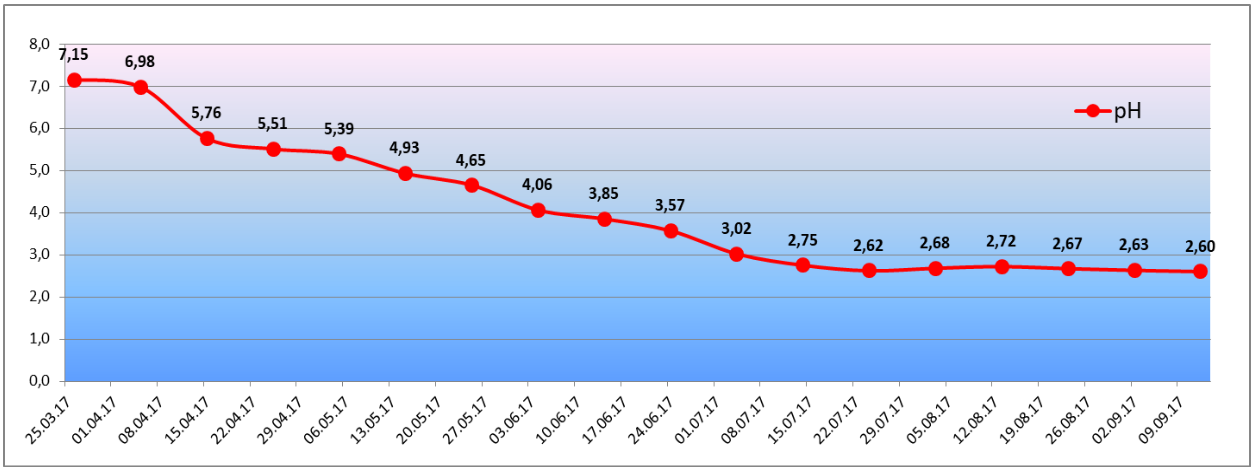



Figure 4 - Changing the value of pH for the block number 1 (network 25×25× 30)

When the technological well arrangement network was 20x20x20 (Figure 5), the sharpest decrease in pH values was obtained in a short period (25-30 days), which indicates an increase in the filtration coefficient due to a reduction in the minimum length of the streamline, which may later lead to channeling effect and lack of time for the passage of the reaction in the ore horizon.

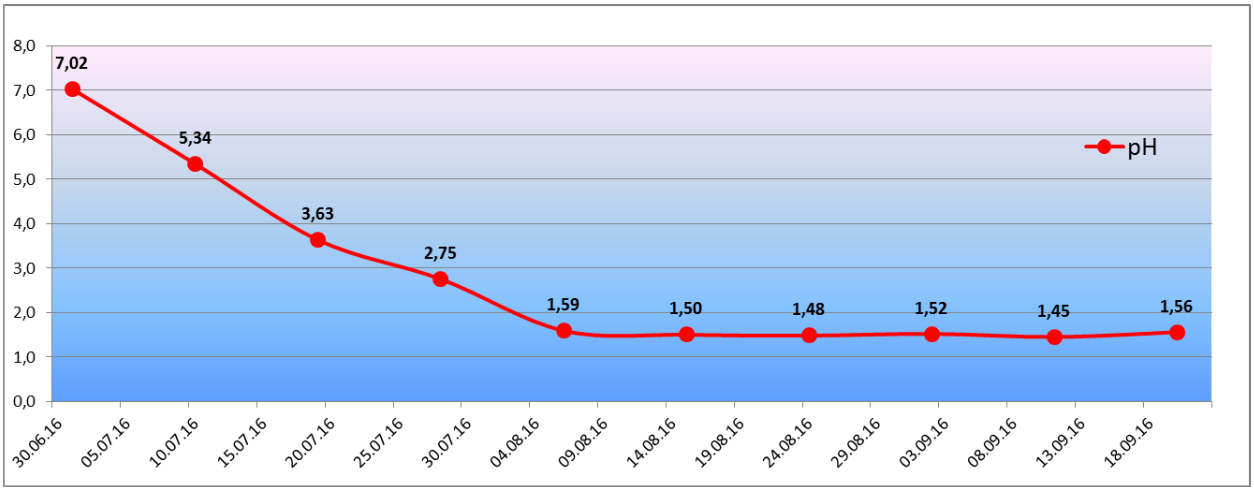



Figure 5 - Changing the value of pH for the block number 2
(network 20×20×20)

When the technological well arrangement network was 25x25x25 (Figure 6), the process of lowering the pH is stable and even. The required pH values for the effective course of the process were obtained during the period of 60-70 days.

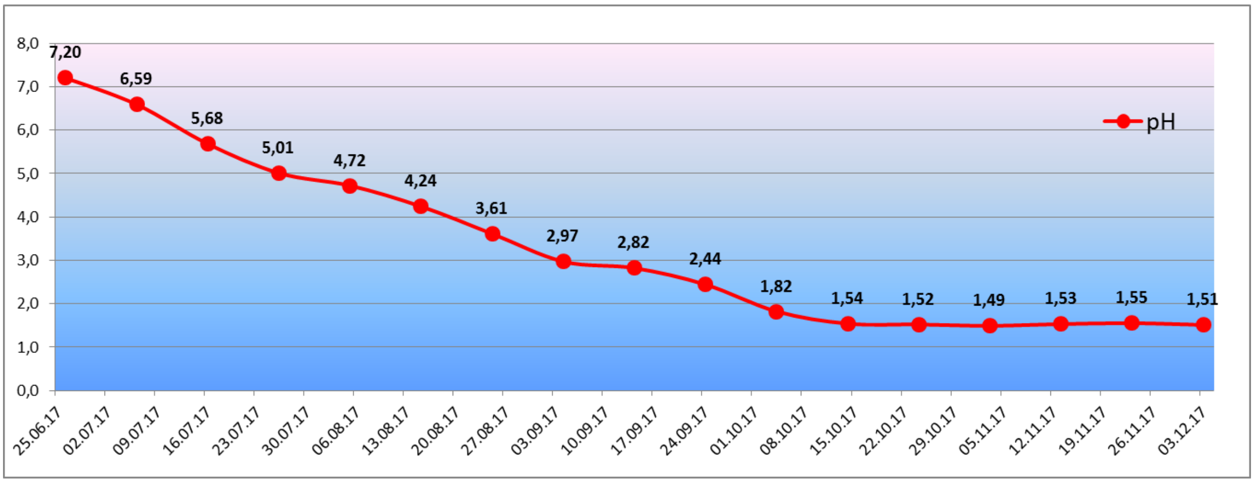



Figure 6 - Changes in the pH value in the block number 3
(network 25×25×25)

To confirm the obtained data and to obtain the dependence of the concentration of sulfuric acid and pH on the distance between the wells with different patterns additional studies were conducted. By processing statistical data, dependences of the concentration of sulfuric acid and pH on the distance between the wells were obtained for various patterns (Figure 7).

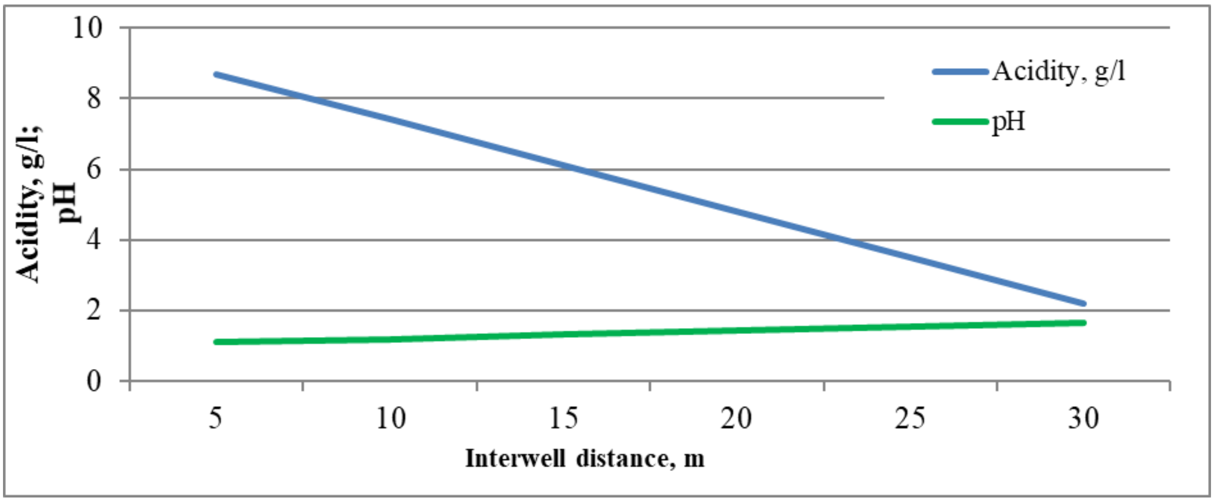



Figure 7- The dependence of the concentration of sulfuric acid and pH on the interwell distance.

Analysis of the operation of various patterns for the location of wells has led to the conclusion that an increase in the distance between the wells leads to a decrease in the content of sulfuric acid in the “pregnant” solution along the streamline and an increase in pH.

When the distance between the wells is 20-25 meters (row pattern), the concentration of sulfuric acid decreases to 4 g / l - 2.8 g / l when approaching the pumping well. These values correspond to pH values of 1.5-1.7, that is, there will be no significant sedimentation of colmation elements. When the distance between the wells is 30 m, the concentration of sulfuric acid decreases to 1 g / l, respectively, the pH is 1.9, and this is an area of significant precipitation. This data allows us to conclude that the optimal distance between the wells is 25 meters.

To confirm the obtained results, observation wells were constructed on technological blocks with different technological wells patterns. Testing and induction logging was conducted in these wells, starting from the initial stages of acidification and up to the period of active leaching.

The diagram (Figure 8) shows the result of determining the degree of acidification of rocks based on induction logging data. This well is located in the center of the block that was drilled out by 25 x 25 x 30 pattern. Technological solutions of this block that have passed through the ore rock, where the test well is located, affected the electrical properties of the ore-bearing rocks.

The dynamics of acidification of the block under study is clearly expressed in changes in the diagrams of periodically conducted induction logging. According to the data of these curves, the acidification at the network of 25x25x30 occurs rather slowly. Thus, the data of the inductive logging confirm the conclusions made on the pH values obtained in the result of testing.

The diagrams (Fig. 9) show the changes in the degree of acidification of the ore mass in time with the technological well network of 25x25x25.

On the curves shown, it is seen that the acidification of the upper ore level, located between the two aquicludes passes faster than the lower ore horizon. However, the lower ore level reached certain electrical conductivities corresponding to a high degree of acidification much faster in time at the network of 25x25x25 than at the network of 25x25x30.

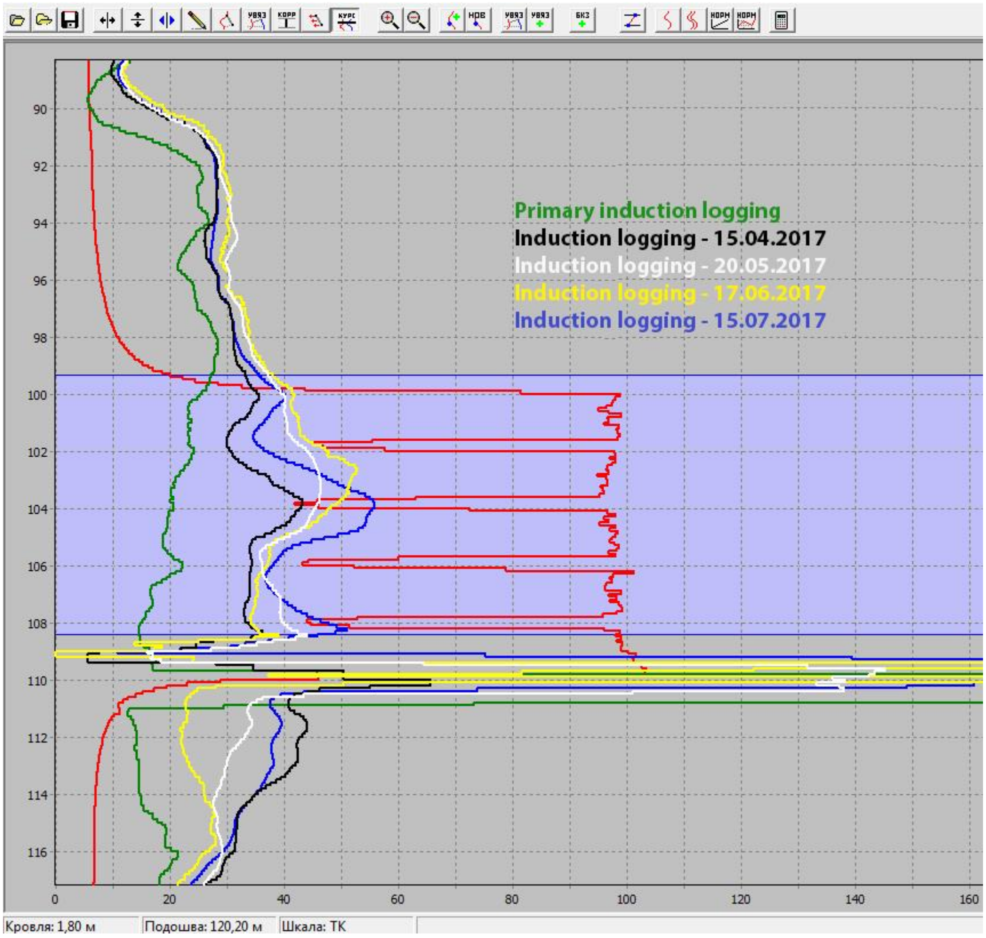



Figure 8 - Diagrams of induction logging changes in time with a network of 25×25×30

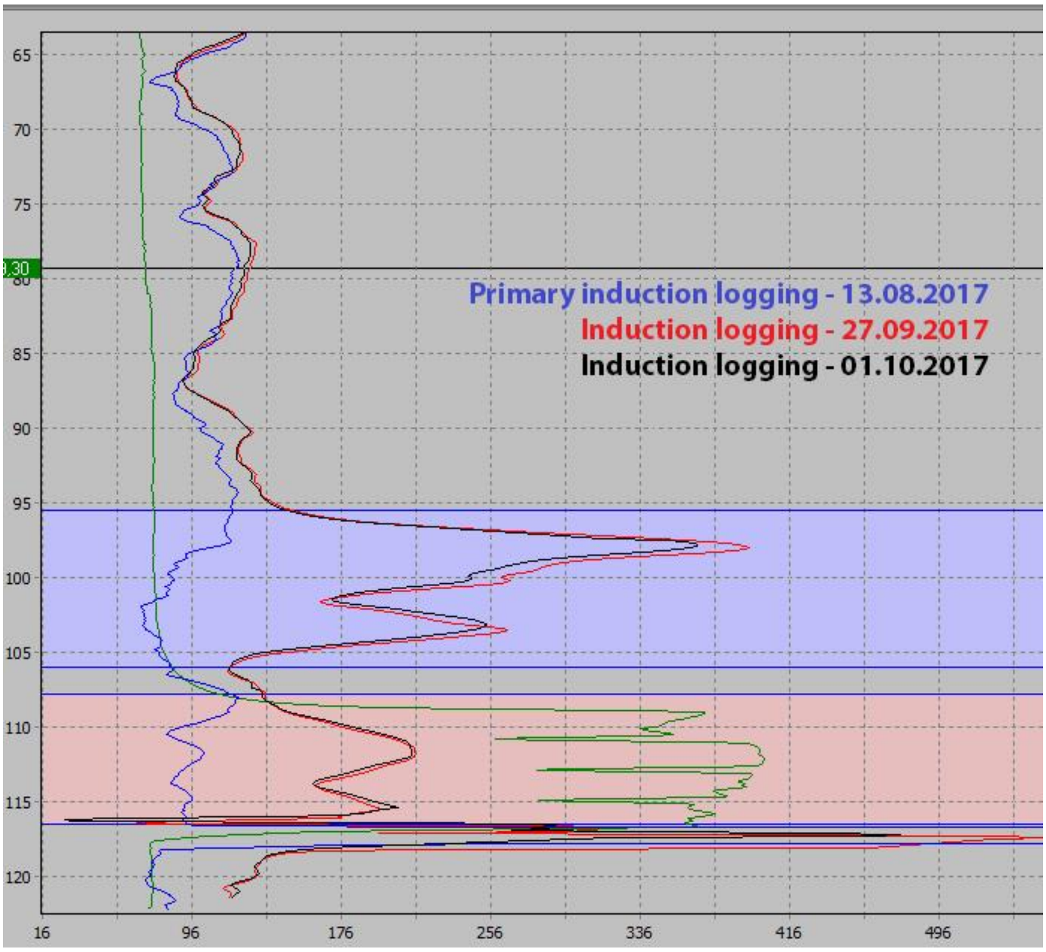
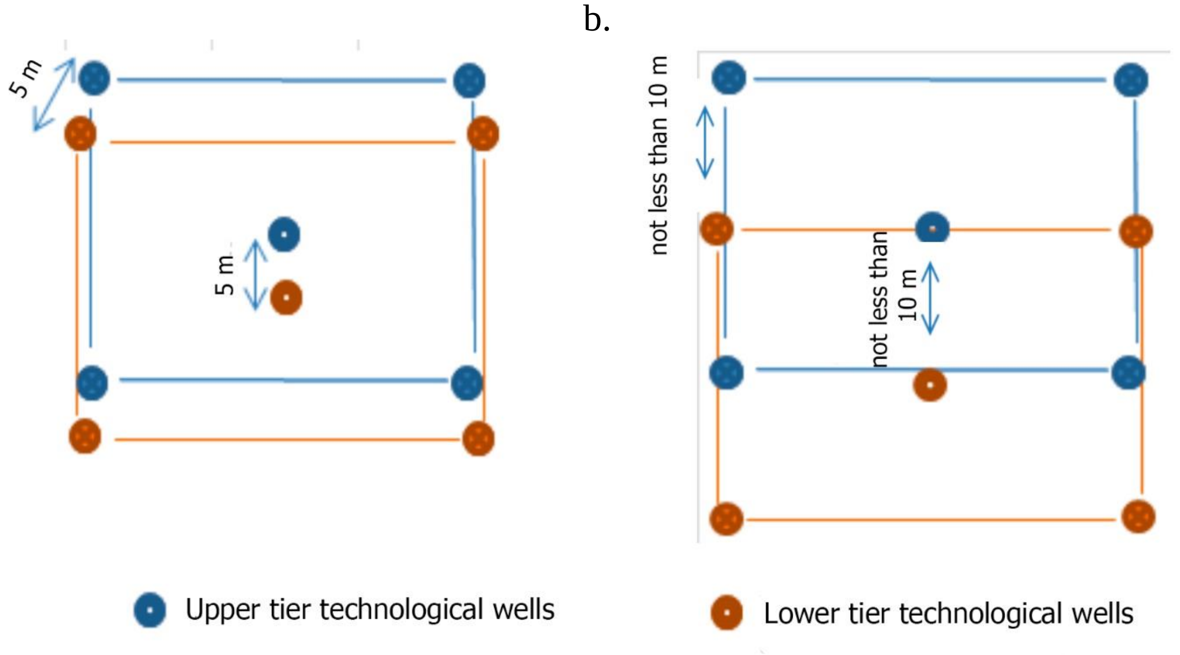



Figure 9 - Well acidification zone after 49 days (25×25×25)

Summarizing the information presented above, it can be concluded that when using the 25x25x25 network in a row "envelope" scheme, when square cells with four injection wells and one pumping pump are created, the construction of excess technological wells is practically excluded. The use of this network leads to a stable process flow, and, in turn, to the optimal block processing time and rational consumption of reagents.

At present, all hydrogenic uranium deposits are involved in the development of the ISL method, which often have several ore bodies with a longline of their location in the productive horizon. As a rule, these ore bodies are not limited vertically to stable aquicludes and, as a rule, are located at a distance of 8 to 50 m from each other. At the same time, the distance between technological wells of the upper and lower ore horizons is no more than 5 meters (Figure 10a). The application of this well pattern leads to the difficulty of maintaining the geotechnological balance of solutions, increase of hydraulic pressure on certain areas and the duration of technological block development.

To eliminate the above drawbacks, a pattern for drilling of multi-tiered ore bodies under complex hydrogenous deposits is proposed, presented in Figure 10




a) b)

a) the existing pattern of multi-tiered ores drilling;
b) the proposed pattern of multi-tiered ores drilling.
Figure 10 - Patterns of multi-tiered ores drilling

To eliminate the above drawbacks, a pattern for drilling multi-tiered ore bodies under complex hydrogenous deposits is proposed, presented in Figure 10 b.

The principal difference of the proposed pattern is that the lower ore horizon technological wells must be located in the middle of the interwell distance of the upper ore horizon technological wells. Thus, the distance in the plan between the wells to the upper and lower horizons will be at least 10 meters. The balanced distribution of wells in a rarefied network in the plan reduces the hydraulic pressure on the aquiferous ore horizon. This entails a more efficient distribution of technological solutions in the reservoir and their free circulation, eliminating the effect of "channeling" due to excessive pressure on certain areas.

This pattern will allow to solve problems with the observance of the balance of technological solutions, due to the reduction of the hydraulic pressure. This will also entail a reduction in the number of repair works carried out at injection wells due to their compliance with the prescribed parameters. It will also be possible to reverse the wells between the rows in the horizon, regardless of the operation of the pair well in another horizon. Since it is partially excluded the overpressing of solutions between horizons.

The operation of technological wells in the conditions of the Semizbay field confirms that there is a formation of chemical colmation, which is represented by silicon compounds. With a good flow rate at the beginning of operation, it gradually decreases. In this case, measures (swabbing, air-lift pumping with compressed air, chemical treatment) aimed at increasing the flow rate do not bring the expected result.

In order to solve this problem, we proposed a method of using ammonium bifluoride in the presence of sulfuric acid solution to increase the dissolution of colmation substances.

In order to avoid the loss of ammonium bifluoride in the course of the reaction, a loading box was installed at the mouth of the casing string of the well through which ammonium bifluoride was poured directly into the well without prior dissolution. Further, by lowering the drain hose into the casing of the well to a depth below the static level of 5-10 m and securing it to the wellhead, an in-depth chemical treatment was carried out with a high acidity leaching solution. The feed rate of the high acidity leaching solution into the well was regulated by a drain valve depending on well injectivity.

The waiting time after the supply of ammonium bifluoride ranged from 24 to 48 hours. Ammonium bifluoride consumption per treatment of one technological well was 15-50 kg. After waiting for the well to be settled in the reagent treatment mode, an air-lift pumping of the filter zone of the well and the sump was carried out until the solutions were clarified to remove dissolved colmation.

As a result of chemical treatment according to the above described method, performance rates in technological wells increased from 1.4-2.0 m3 / h to 4.4-5.3 m3 / h, respectively. Thus, an increase in well performance from 48% to 75% is obtained, in some cases up to 150% (Figure 11)

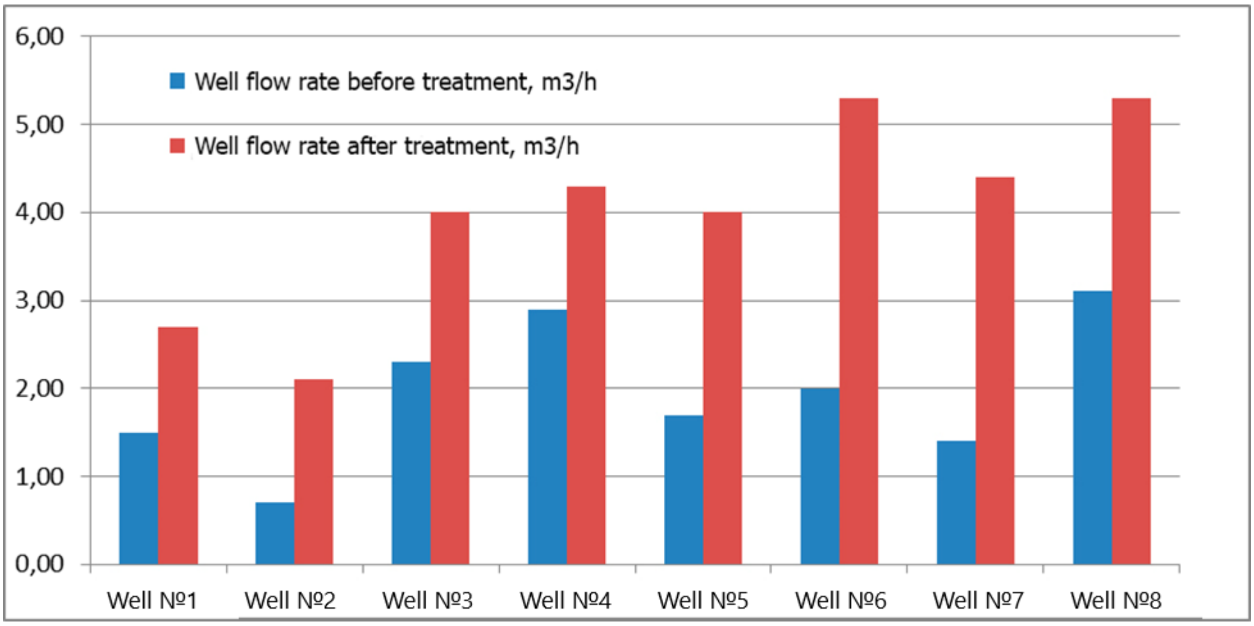



Figure 11 - Changes in well flow rates after the ammonium bifluoride treatment

After the treatment with ammonium bifluoride according to the method proposed in the second stage, the re-treatment cycle, on average, increased by 55 days. From the obtained results, it was concluded that the technique in which ammonium bifluoride is poured into the well without dissolution, and the top is fed with high-acidity leaching solution is more effective. The reaction of formation of hydrofluoric acid takes place directly in the filter zone, reacting with hardly soluble silicon compounds, reducing colmation of the filters of technological wells (Figure 12).

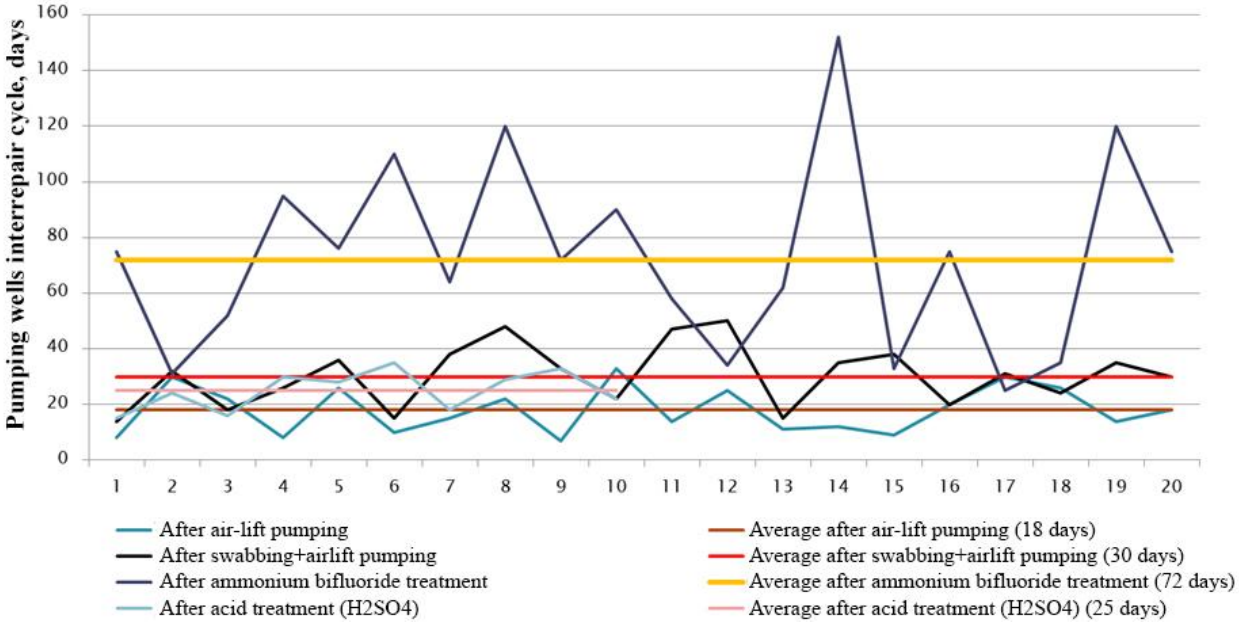



Figure 12 - Comparative analysis of the interrepair cycle after the application of various types of well repair works

Technological wells chemical treatment with acidic solutions using ammonium bifluoride in order to eliminate chemical hardly soluble colmation gives results that satisfy the objectives.

To increase the concentration of uranium in the pregnant solution, we studied the effect of hydrogen peroxide as an oxidizing agent on the leaching process by adding it to the leaching solutions.

It should be noted that the Semizbay field, in contrast to the Shu-Sarysu and Syrdarya provinces, is characterized by a deep secondary recovery, which led to the almost complete disappearance of iron 3+ in the composition of formation water and ore rock. Therefore, to create an oxidizing environment in leaching solutions, pilot works were carried out on the use of iron 2+ as an oxidizing agent to iron 3+ with hydrogen peroxide (with an H2O2 content of up to 60%), with a various acidity of leaching solutions.

A controlled parameter indicating the amount of hydrogen peroxide fed to the oxidation is the RedOx potential value and the concentration of iron 3+ in leaching solutions.

According to the results of the experimental work, the dependences of the uranium content on the concentration of sulfuric acid and hydrogen peroxide in the studied technological blocks and wells were obtained.

At the first stage, hydrogen peroxide was supplied to experimental process block A under low acidity conditions (3-5 g / l) of leaching solutions for 40 days (Fig. 13).

The average peroxide concentration was 0,4 l / m3 of leaching solution. As can be seen in Figure 13, after 24 days from the beginning of the supply of hydrogen peroxide, there was a slight increase in the uranium content of 6–8 mg / l.

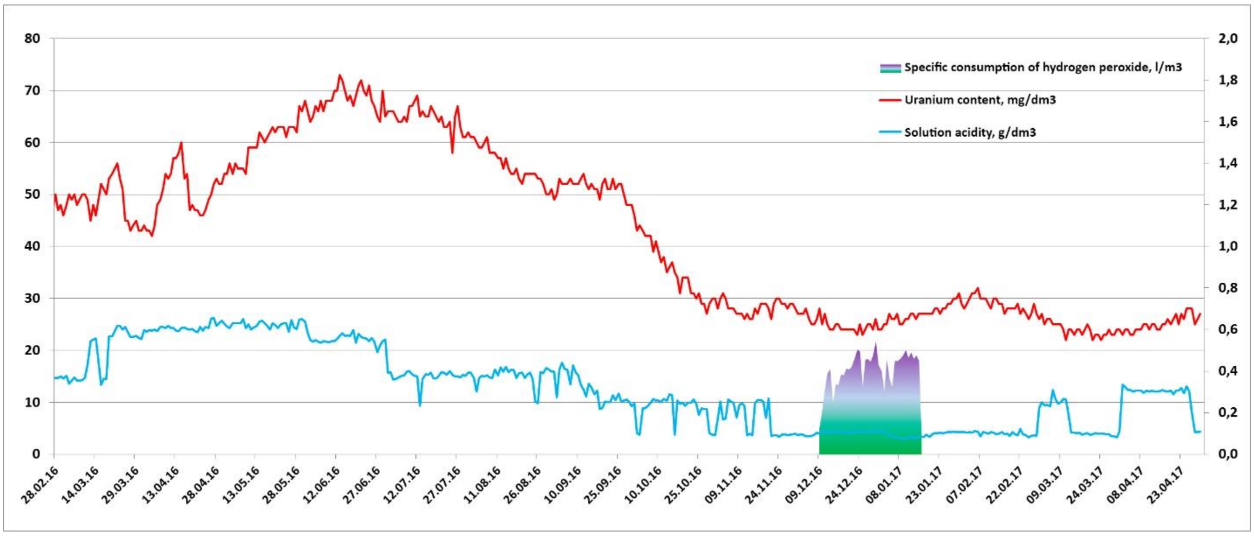



Figure 13 - Hydrogen peroxide supply in low acidity conditions (3-5 g / l)

At the second stage of experimental work, technological peroxide B was supplied with hydrogen peroxide at a concentration of sulfuric acid in leaching solutions ≈ 15-18 g / l (Figure 14). After a short period of time from the beginning of the supply of hydrogen peroxide, an increase in the concentration of uranium in the productive solutions was observed.

After stopping the supply of hydrogen peroxide to the technological block, the concentration of sulfuric acid in the leaching solution remained at 15-18 g / l. However, there was a steady significant decrease in the concentration of uranium in the “pregnant” solution.

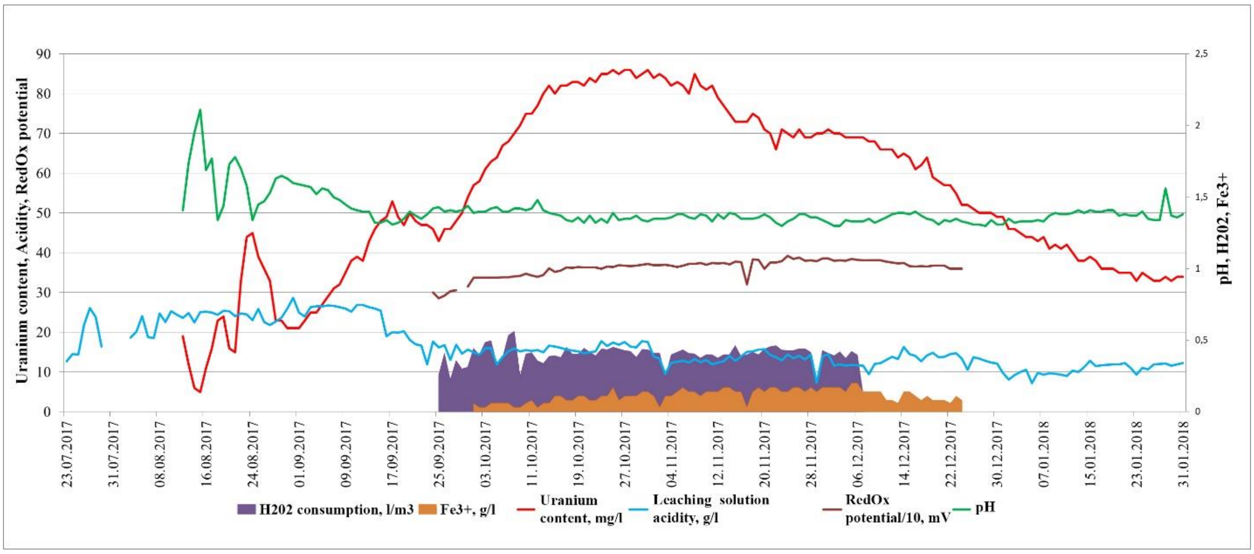



Figure 14 - Hydrogen peroxide supply in conditions of medium acidity (15-18 g / l)

At the third stage, hydrogen peroxide was fed into separate wells. For experimental work, two wells were selected, one of which is located in the center of the block, and the second is a single push-pull well. Below in Figures 15 and 16 there are graphs of the operation of these wells when applying leaching solution with only sulfuric acid, and subsequently with the addition of hydrogen peroxide.

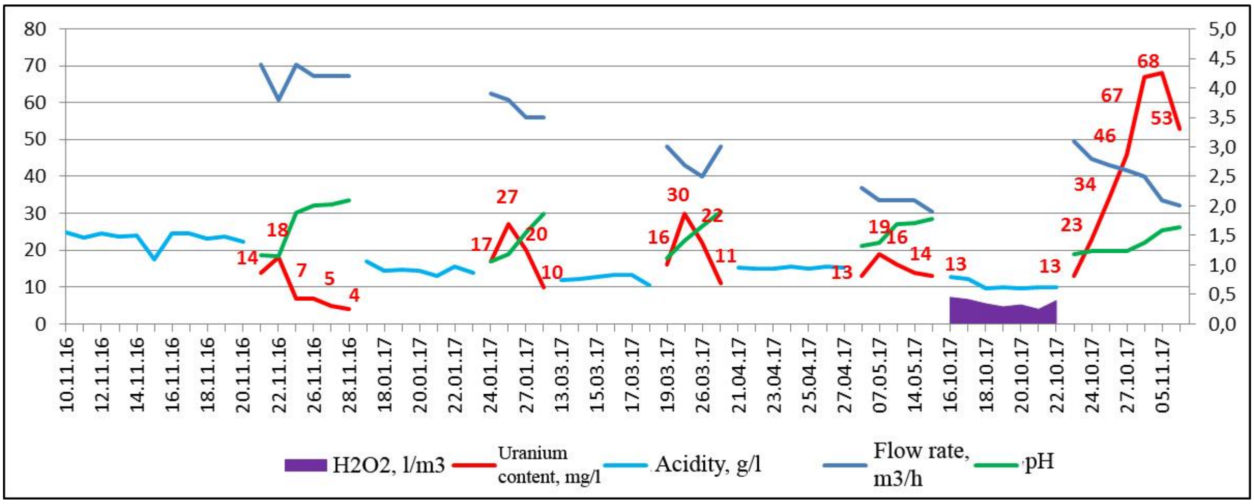



Figure 15 - Hydrogen peroxide supply in appointed well (pointwise), universal well in the center of the block.

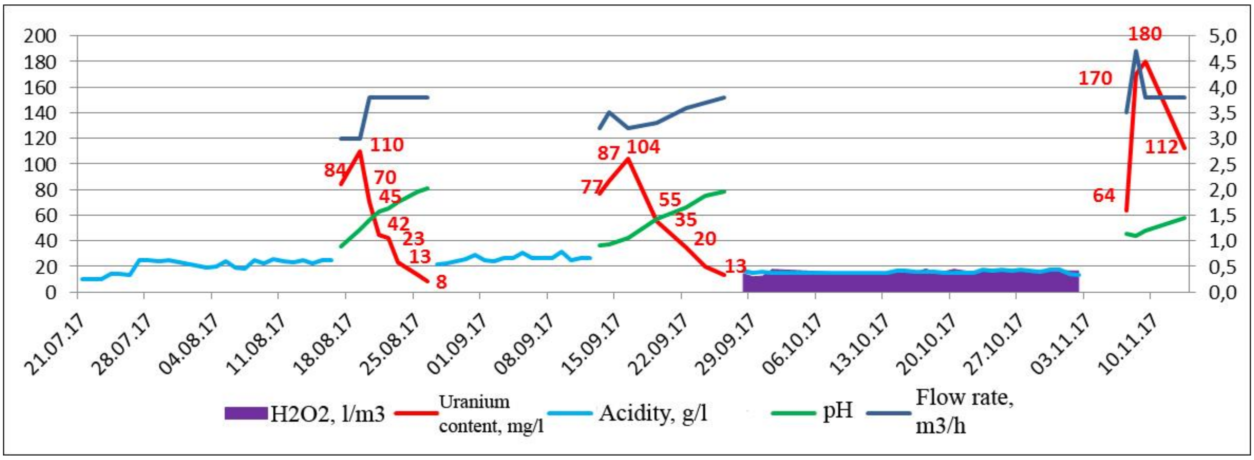



Figure 16 - Hydrogen peroxide supply in appointed well (pointwise), "push-pull" well

The results of using hydrogen peroxide at the Semizbay mine clearly show that the use of hydrogen peroxide has a positive effect on increasing the concentration of uranium in the “pregnant” solutions by an average of 25%. At the same time, the optimal conditions for the supply of hydrogen peroxide are to ensure the concentration of sulfuric acid in leaching solutions in the value of not less than 13-15 g / l. Otherwise, the positive effect of hydrogen peroxide is significantly reduced. The most preferred is the supply of hydrogen peroxide to the blocks with a low extraction ratio, at the initial stage of active leaching.

**Brief conclusions on the results of research.**

1. Problems with the application of in-situ leaching technology is a decrease in the performance of technological wells as a result of colmation of filters and filter zones of the aquifer, improper selection of the well paterns.

2. For the conditions of the Semizbay field, it is more effective from the point of view of providing the required well performance and reducing the colmation frequency is the raw well pattern.

3. For leaching of contiguous ore deposits, a technological well pattern has been proposed, which is characterized in that the technological wells of the lower ore horizon must be located in the middle of the technological wells of the upper ore horizon. Uniform distribution of wells in a discharged network in projection reduces the hydraulic point load on the aquiferous ore horizon. This entails a more efficient distribution of technological solutions in the reservoir and their free circulation, eliminating the effect of "channeling" due to excessive pressure on certain areas.

4. Well flow rate dependencies were obtained before and after well repair using ammonium bifluoride. Chemical treatment of technological wells using ammonium bifluoride solutions gives positive results of proper quality. Chemical treatment led to an increase in production rate in technological wells from 1.4-2.0 m3 / h to 4.4-5.3 m3 / h, i.e. the flow rate increased from 48% to 75%, respectively, and in some cases up to 150%.

5. To reduce the leaching time and increase the extraction, it was proposed to use hydrogen peroxide taking into account the concentration of sulfuric acid in the leaching solutions. For the conditions of the Semizbay field, the use of hydrogen peroxide has a positive effect on increasing the concentration of uranium in the pregnant solutions by an average of 25%.

**Evaluation of the completeness of the solutions of the tasks.**

The following tasks are solved in the work:

- dependencies of productivity and frequency of colmation of technological wells on the pattern were established, which allows increasing the interrepair cycle of the wells and reducing the cost of uranium leaching;
- dependences of pH value on the pattern and parameters of technological wells were obtained, which leads to a stable, uniform process of ISL and rational consumption of reagents;
- dependencies of the performance of technological wells on the amount of ammonium bifluoride used in repair works, which will increase the interrepair cycle, as well as the uranium content in the pregnant solution from the use of hydrogen peroxide in the leaching solution.

The tasks in the thesis to improve the effectiveness of various in-situ leaching patterns for the development of hydrogenic deposits are fully resolved, the goal of the thesis has been achieved. A row well pattern and a network of well drilling of 25x25x25m, as well as the necessary concentration of ammonium bifluoride and hydrogen peroxide, are proposed.

**Recommendations and baseline data on the specific use of research results.**

Based on the completed researach:

- For the Semizbay field, it is recommended to use the row pattern of wells and their drilling network of 25x25x25m, that leads to a stable, uniform process flow and rational consumption of reagents.
- The necessary pH values for an efficient leaching process are achieved with the expiration of 60-70 days.
- For carrying out repair works, the concentration of ammonium bifluoride 25 kg per 1 technological well is recommended.
- When using hydrogen peroxide, the required concentration of sulfuric acid in the leach solution should be at least 13-15 g / l.

**Evaluation of technical and economic efficiency.**

The economic effect from the implementation of the research results is calculated on a block of 15 thousand m2, taking into account the increase in the interrepair cycle of the well operation by 15% and the metal concentration in the productive solution by 25% and is 41485552,6 tg.

**Evaluation of the scientific level of the work performed in comparison** with the best achievements in this field.

The assessment of the scientific level of the work performed was carried out on the basis of the analysis of research works of the CIS and foreign countries. The analysis of the literature, the results of theoretical and conducted research presented in this dissertation, allow us to conclude that it corresponds to the modern scientific and technical level.

Studies on the choice of the pattern and network of wells for the development of complex hydrogenous uranium deposits, taking into account the pH value, have not yet been carried out. At operating enterprises, the concentration of ammonium bifluoride and the use of hydrogen peroxide is accepted by analogy, without taking into account the geological features of the field, therefore the thesis brings novelty to a scientific world and corresponds to the world level and trends in the development of uranium in-situ leaching technology.

**The main results of research on the thesis are published in the following papers.**

1. Dzhakupov D.A., Increasing the efficiency of Uranium mining by the method of in-situ leaching, International Scientific and Technical Conference “Innovative Development of the Mining Industry” December 14, 2016, Kryvyi Rih, Ukraine

2. Yusupov Kh.A., Aliev S.B., Dzhakupov D.A., Elzhanov E.A. Application of ammonium bifluoride for chemical treatment of wells during uranium in-situ leaching / ISSN 0017-2278 Mining Journal, 2017 Moscow №4 (Scopus)

3. Yusupov Kh.A., Dzhakupov D.A., Nazarbayeva N.A., Choosing a pattern and parameters of wells of the technological block. International scientific and practical conference “Scientific and personnel support for the innovative development of the mining and metallurgical complex” on April 27-28. , Almaty.

4. Dzhakupov D.A. The impact of technological wells curvature on the leaching indicators of Uranium / Works of the Satpayev Readings “Innovative solutions to traditional problems: engineering and technology”

5. Dzhakupov D.A. The choice of the technological wells pattern in the development of multi-layered ore deposits. International Scientific and Practical Conference "Modern scientific research: topical issues, achievements and innovations", Penza, 2018, ISBN 978-5-907135-46-8 Part 1 BBK 60

6. Yusupov Kh.A., Dzhakupov D.A., Bashilova E.S., Improving the mining efficiency of complex hydrogenic uranium deposits using hydrogen peroxide. Mining Journal of Kazakhstan, 2018, No. 2, Almaty, ISSN 2227-4766

7. Yusupov Kh.A., Dzhakupov D.A., The effect of the concentration of sulfuric acid on the distance between the wells in the uranium leaching. The Mountain Journal of Kazakhstan, 2018, No. 2, Almaty, ISSN 2227-4766

8. Yusupov Kh.A., Dzhakupov D.A., Bashilova E.S. The impact of technological blocks drilling pattern in uranium mine development. Proceedings of the University 2018, No. 3, Karaganda, ISSN 1609-1825