Kazakh National Research Technical University named after K.I. Satpayev

Удк 622.27 **As a manuscript**

KHAIRULLAYEV NURSULTAN BATYRKHANOVICH

Increasing the efficiency of ISL uranium with solution activation

6D070700- Mining engineering

Dissertation for an academic degree
(PhD)

Scientific consultants
Aben E.Kh., Candidate of technical sciences, assistant professor

Aliyev S.B., Doctor of Technical Sciences, professor

Republic of Kazakhstan
Almaty, 2022

The raw material base of enterprises mining uranium by in situ leachings is currently mainly poor deposits of hydrogenic genesis, occurring in permeable sandy-clay sediments of depression zones of the earth's crust, and gold by heap leaching - lean and off-balance ores. Until recently, these deposits, which contain uranium and gold reserves, were not involved in industrial development by traditional mining methods for technical and economic reasons. This important task, which is of great national economic importance, has been largely accomplished by now. Especially in the last decade, extensive work has been carried out to develop and implement on an industrial scale geo-technological mining of uranium, called the method of in-situ leaching (ISL).

Underground leaching is a method of mining uranium by selectively dissolving it with chemical reagents from ores at the place of their occurrence and then extracting it from solutions containing uranium. Underground leaching is an alternative to open pit and underground mining. Compared to them, underground leaching does not require a large amount of excavation or direct contact of workers with rocks at their location. Effective even in poor deposits, as well as for deep-seated ores.

Despite its advantage, there are several disadvantages, the main of which is an increase in the cost of production and a decrease in the content of the useful component in the rock mass. As you know, leaching is associated with the processing of large quantities of raw materials, the cost of leaching reagents largely determines the cost of the final product, since the cost of reagents is 27 - 45% of the operating costs of leaching.

There are various ways to increase the recovery of the uranium content in the productive solution. But they are expensive and technologically difficult to use. Therefore, it is an important task to increase the efficiency of ISL of uranium by increasing the uranium content in the productive solution and reducing the production cost.

The purpose of this work is to increase the uranium content in the productive solution and reduce the consumption of the reagent in the in-situ leaching of uranium with the activation of the leaching solution.

The research objectives are:

- study of the geological features and analysis of the applied ISL technology for uranium at the Central Mynkuduk deposit;
- analysis of literary sources and research works on improving the efficiency of uranium ISR;
- development of a technology for activating the leaching solution;
- laboratory studies to establish the influence of the holding time of the leaching solution after activation on the uranium content in the productive solution;
- laboratory study of the effect of the activated solution on the uranium content in the productive solution at various concentrations of the reagent and the establishment of the degree of activation;
- pilot testing of the proposed technology;
- processing of research results and issuing a recommendation.

The novelty of the topic lies in increasing the uranium content in the productive solution and reducing the consumption of the reagent by mechanically activating the working solution.

Provisions for defense:

- activation of the leaching solution before it is fed into the injection well leads to an increase in the uranium content in the productive solution and reduces the consumption of the reagent. For example, under production conditions, the increase in the uranium content was 8%, and the consumption of the reagent decreased due to a reduction in the period of block development;
- the content of uranium in the productive solution depends on the activation time of the leaching solution and the leaching time. For example, with a change in the leaching time to 5 minutes, activation of the solution for 3 minutes leads to an increase in the uranium content in the productive solution by 10%, at 5 minutes - by 21% and at 10 minutes - by 18%;
- over time after the activation of the leaching solution, a slight decrease in its activity is observed, but its activity remains up to 30 days. For example, when the solution is activated for 3 minutes and then leached for 5 minutes, the following results are obtained: immediately after its activation, the uranium content in the productive solution increases by 10%, after holding for 2 hours - by 9.5%, after 30 days - by 9%.

Scientific novelty of the work:

- a technology was developed to increase the uranium content in the productive solution, which is distinguished by the treatment of the leaching solution at the activation unit before it is fed into the injection well;
- the dependence of the uranium content in the productive solution on the activation time of the leaching solution was obtained, which makes it possible to establish the optimal activation time and ensure the maximum uranium content in the productive solution;
- the dependence of uranium content in the productive solution on the holding time of the leaching solution after activation was obtained, which will make it possible to establish a decrease in the activity of the leaching solution during its transportation from the place of activation to the reservoir.

The relationship of this work with other research works. The dissertation work was carried out within the framework of business contract No. 50 - LLP - 19 dated 02.20.2019 "Development of technology for intensification of denitration and leaching processes in the conditions of the site "Central" of the "Mynkuduk" field.

The object of research is the Central Mynkudyk field located in the Sozak district of the Turkistan region.

The subject of research is the technology of activation of the working solution during the ISL of uranium.

Methodological base of research.

- analysis of the current state of the use of the ISL of uranium and research to improve its efficiency;

- development of methods for conducting laboratory tests;
- carrying out laboratory and pilot work;
- collection and analysis of statistical data;
- processing of research results and issuing a recommendation.

The practical significance of the dissertation lies in the development of a technology for mechanical activation of the working solution to increase the uranium content in the productive solution and reduce the consumption of the reagent.

Publications and approbation of work. The results of the work were reported at international scientific-technical and scientific-practical conferences:

- Satpayev readings on the topic " Innovative technologies are the key to successfully solving fundamental and applied problems in the ore and oil and gas sectors of the economy of the Republic of Kazakhstan " 2019 (year) ;
- Collection of scientific papers of the 15th international conference on the problems of mining, construction and energy industries. Minsk - Tula - Donetsk, October 29 - 30, 2019;
- Satpayev readings 2020 - 2021 on the topic "Development of ore and non-metallic minerals"; 2021 year.

Publications include articles in the magazines "Mining Journal of Kazakhstan" (Almaty, 2021), "Integrated use of mineral raw materials" (Almaty, 2021), "News of Science of Kazakhstan" (Almaty, 2021), as well as in the rating magazine "Mining of mineral deposits", (Dnipro, 2019).

Structure and scope of work: The dissertation consists of an introduction, 3 chapters, a conclusion, a bibliographic list of 21 titles and contains 65 pages of typewritten text, 35 figures, 13 tables and 3 applications.

The author expresses his sincere gratitude and gratitude to the scientific advisers, Associate Professor Aben E.Kh. and Professor Aliyev S.B. for useful advice, valuable comments, and constant attention during the course of this work.

Main part

The Mynkuduk field is the Central site, which is located in the central part of the Chu - Sarysu province.

The village of Shieli which is located 240 km away from the field is the nearest railway station. Communication with railway stations and the area of work is carried out by special vehicles. There are no settlements near the Mynkuduk field. The nearest settlements are the village of Kyzemshek, which is 96 km away, and the village of Taikonur, which is 70 km away.

The ores of the Mynkuduk horizon in terms of the mineralogical composition of the Mynkuduk deposit, and in particular the Central area, are coffinite - pitchblende. The site Central includes deposits 8 and 10, localized in the Mynkuduk horizon given in Table 1.

Table 1 - Characteristics of the size of ore deposits of the Central site of the Mynkuduk field

No. of deposits	Profile intervals		Length km	Width of deposit, m		Depth of the bottom of the deposit, m	Position in relation to the lower waterproof, in % to the area of the deposit		Share of reserves in the total for the field,%
	from	to		from	to		less than 10m	more than 10 m	
8	288	212	8,8	50	1300	305-345	82	18	9,2
10	212	48/1	26,4	50	800	340-365	84	16	27,1
18	48/1	620	1,1	50	320	300-315	65	35	0,3
Total for the site			36,3				77	23	36,6

The uranium content and the thickness of the ore bodies vary within wide limits: from 0.015 to 0.177% and from 0.90 to 16.80 m, respectively.

As of 01.10.2018, at the Central block of the Mynkuduk field, 70 technological blocks are in operation at the stage of active leaching, of which 58 technological blocks (data excluding the combination of technological blocks) are opened by a hexagonal scheme, and 12 technological blocks are opened by an in-line scheme.

Based on the morphological parameters of ore bodies, the accepted network of wells, the material composition of ores and host rocks, the water-physical properties of the productive horizon, acidification will be carried out with leaching solutions with a sulfuric acid concentration of up to 25 g/l with a duration of 1.3 to 4.7 month to obtain productive solutions with an industrial concentration of uranium (40 - 50 mg/l) and pH <3.

According to the results of experimental work at the field, the production rate of the pumping wells varies from 5.8 to 7.2 m^3/h; while the injection rate is 2-4 m^3/h.

The stage of active leaching is marked by the intensity of the transition of uranium into the productive solution and its transfer to the pumping wells.

In the conditions of the field, the concentration of working solutions of sulfuric acid must be maintained at the level of 6-8 g/l. At the same time, by varying the content of sulfuric acid within the specified limits, it is necessary to maintain the pH in productive solutions at a level of 2.0 - 2.2 units.

An analysis of the leaching technology in this field showed that with an increase in the concentration of sulfuric acid to 25-26 g/l, there is an increase in the uranium content in the productive solution up to 220 mg/l. After reducing the acidity of the leaching solution to a level of 8-10 g/l, there is observed a decrease in the uranium content in the productive solution.

As is known, sulfuric, nitric and hydrochloric acids, soda, sodium bicarbonate (bicarbonate salts) and ammonium carbonate (salts and esters of carbonic acid) are used for leaching uranium. Since leaching involves the processing of large quantities of raw materials, the cost of leaching reagents largely determines the cost of the final product. In mining enterprises, in order to reduce the consumption of acid, many experiments are carried out, since the cost of reagents is 27 - 45% of the operating costs of leaching.

Research part

To reduce the consumption of the reagent, various technological solutions are used, which are distinguished by their high cost and technological difficulties in their application. Therefore, a technology of mechanical activation of the working solution has been proposed, which makes it possible to increase its chemical activity and is characterized by low capital and operating costs.

In the process of studying the effect of activation on the activity of the leaching solution the question arose of what exactly is the main reason for the change in the activity of the reagent, whether it is necessary to activate the entire leaching solution, since activating the entire leaching solution requires significant material costs. This question arose especially acutely after the apparent decomposition under the action of the activation of sulfuric acid.

To determine the real effect of activation, an experiment was carried out, when a leaching solution was prepared from water and sulfuric acid according to the usual technology and its activity was checked according to the regular method. The second solution was prepared with pre-activated water for 5 minutes. The studies were carried out on solutions with an acid content of 10 g/l.

To obtain the activation effect, we made an activation unit (Figure 1). The laboratory unit consists of a closed-loop, which includes an electrically driven centrifugal pump (HC), a flow activator (R), a pipeline, a vessel (V), and a drain valve (Ki).

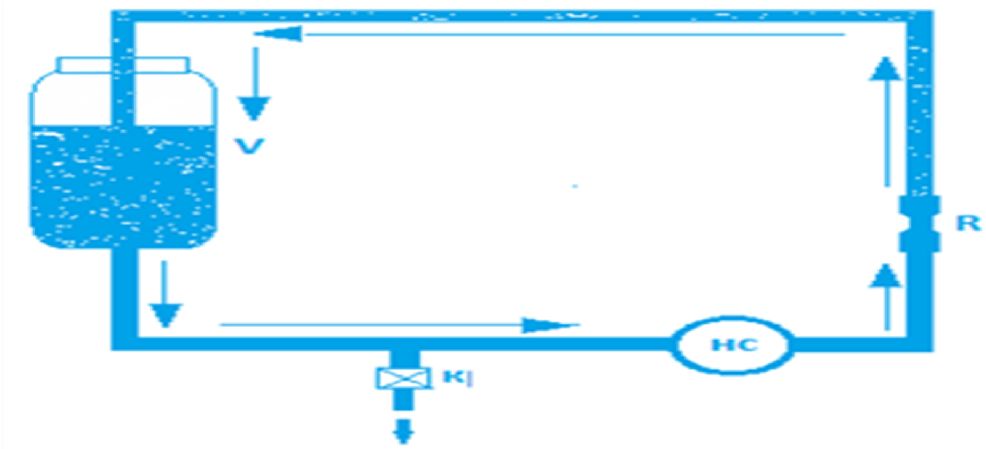


Figure 1 – Laboratory activation unit.

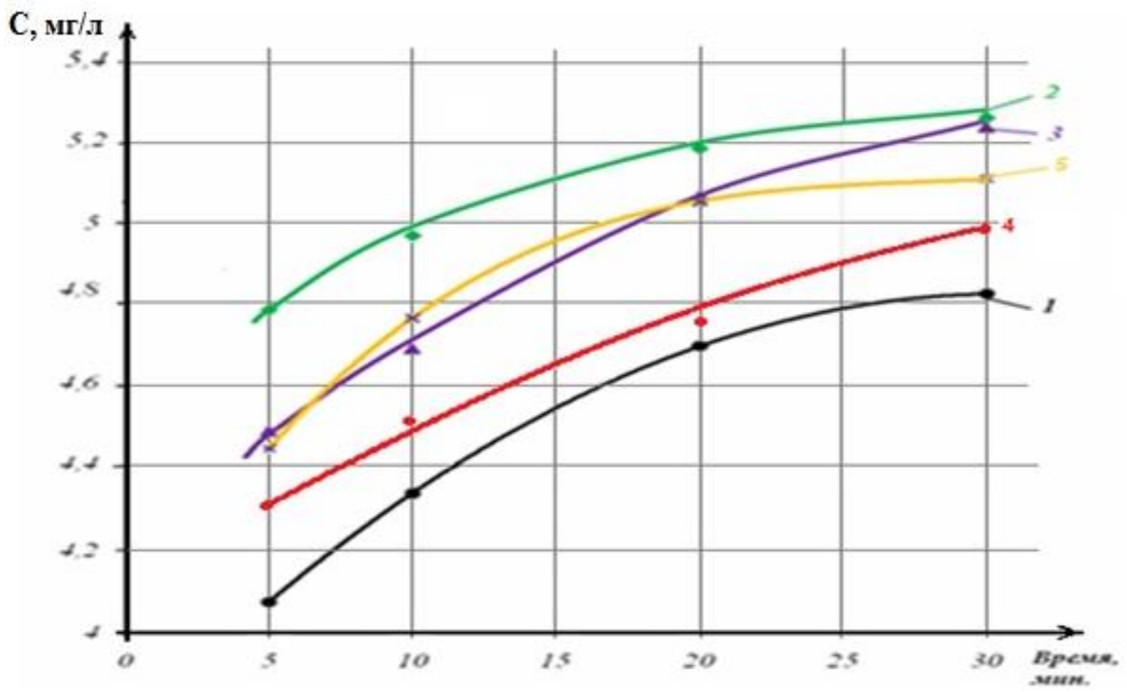
When leaching with a base solution and with the course of leaching time, the uranium content increases from 4.27 mg/l to 4.58 mg/l, then when only water is activated, a decrease in the uranium content is observed in comparison with the base solution from 4.27 mg/l to 4.16 mg/l. Then, after holding the solution for 2 hours, its activity is restored, approaching the values of the properties of the original solution.

The installation was filled with about 1.5 liters of acid and treated for 5 minutes. Then a solution with a content of 10 g/l was prepared from the activated acid and its activity was checked during leaching. The results were compared with the same experiment but without prior activation of the acid.

When leaching with the base solution and with an increase in the leaching time up to 30 minutes, an increase in the uranium content in the solution is observed from 4.08 mg/l to 4.70 mg/l, and when leaching with an activated solution immediately after activation, there was observed an increase in the content from 4,78mg/l to 5.23 mg/l. The performed activation of the solution led to a primary increase in leaching in 5 minutes by 17%.

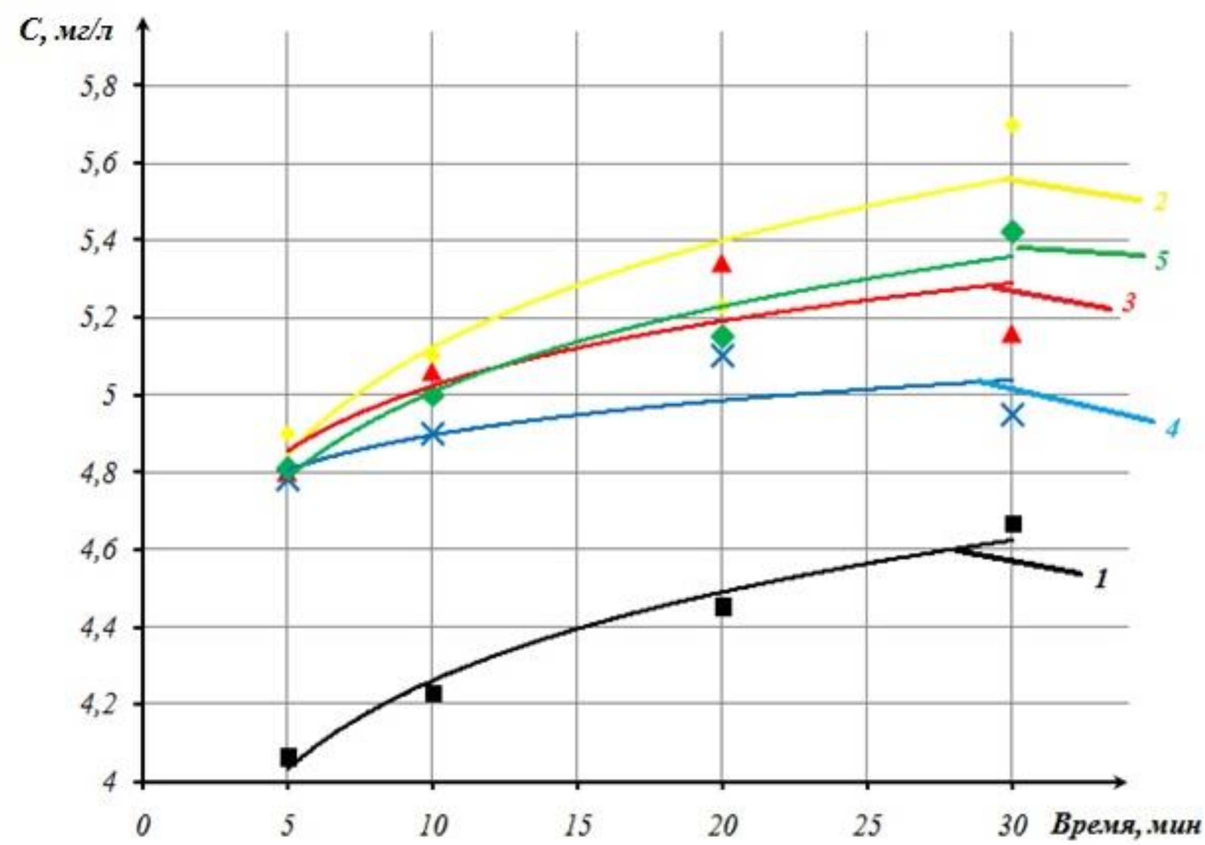
Comparison of the results of measurements of the uranium content in solutions with the activation of only water and only sulfuric acid showed that the activity increased by 14%. Consequently, under industrial conditions, there is no need to carry out mechanical activation of the entire leaching solution; it should be limited only to the activation of re-strengthening concentrated sulfuric acid. This dramatically reduces energy costs.

Further, laboratory studies were carried out to establish the influence of the degree of activation of the leaching solution, the reaction time and the holding time of the solution after treatment on the uranium content in the productive solution. In this case, the degree of activation of the leaching solution was changed for 3, 5 and 10 minutes, the reaction time was 5, 10, 20 and 30 minutes, and the holding time of the solution after activation was immediate, after 2 hours, after 24 hours and after 30 days. In figures 2, 3, 4 is shown the change of the content of uranium in the productive solution depending on the reaction time and the shutter time of the solution after treatment with an activator for 3, 5 and 10 minutes.



1 - the initial state of the solution (before processing); 2 - after processing;
3 - 2 hours after treatment; 4 - after 24 hours; 5- after 30 days
Figure 2 - Change in the content of uranium in the productive solution depending on the reaction time and the holding of the solution in time after treatment with an activator for 3 minutes.

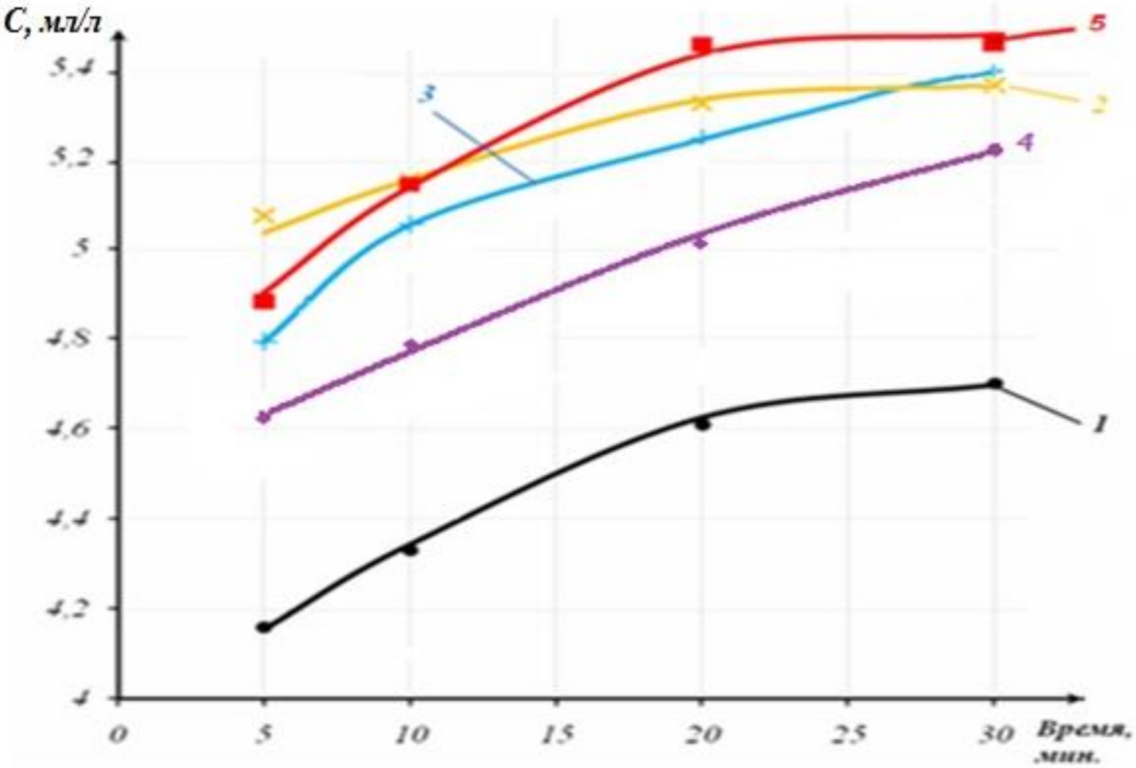
It follows from the analysis that the greatest changes in the uranium content in the solution are observed at a leaching time of 5 minutes (by 17%), and then this difference decreases. The expected significant decrease in the activity of the solution after holding it in time did not occur. With an increase in the holding time of the solution after activation to 30 days, the uranium content in the productive solution slightly decreases, i.e. the activity of the solution is preserved.



1 - the initial state of the solution (before processing); 2 - after processing; 3 - 2 hours after treatment; 4 - after 24 hours; 5 - after 30 days.

Figure 3 - Change in the content of uranium in the productive solution depending on the reaction time and the holding of the solution in time after treatment with an activator for 5 minutes.

Studies have established that initially, the activity of the solution increased by 20.5% in 5 minutes of leaching, and after 10 minutes - by 21%. At the same time, there is also a slight decrease in the activity of the solution after activation over time up to 30 days. In general, it can be assumed that the primary activity immediately after treatment of the electrolyte with an activator and for 30 days remains constant.



1 - the initial state of the solution (before processing); 2 - after processing; 3 - 2 hours after treatment; 4 — after 24 hours; 5 - after 30 days

Figure 4 - Change in the uranium content in the productive solution depending on the reaction time and holding the solution in time after treatment with an activator for 10 minutes.

An increase in the processing time of the solution to 10 minutes led to an increase in activity at 5 minutes of the leaching reaction by 25%. When processing the solution, there was a noticeable evolution of sulfur dioxide. This is due to the insignificant evaporation of sulfuric acid. Within 2 hours, the activity of the solution decreased to 8.0% and was kept in this state for a long time.

Thus, the activation of the solution leads to an increase in the content of the useful component in the productive solution. However, in the course of the conducted studies, it was found that with an increase in the activation time, the density of the leaching solution changes, which can affect the gravitational and, accordingly, the process of sedimentation of the productive solution. This in turn may lead to a change in uranium recovery. By processing the data of the study, graphs of the change in the density of the solution and the content of uranium in the productive solution were obtained.

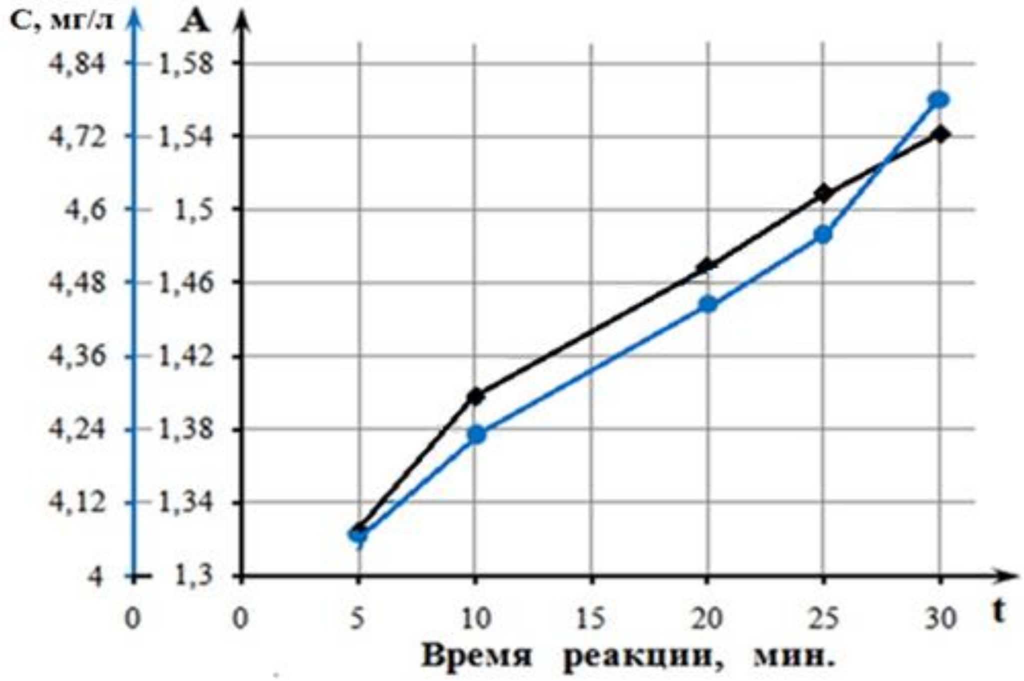


Figure 5 - Graph of the change in density (A) and the content of uranium in the productive solution (C, mg / l) from the time the solution was treated with an activator

CONCLUSION

1. In-situ leaching is associated with the processing of large quantities of raw materials, the cost of leaching reagents largely determines the cost of the final product. To reduce the consumption of the reagent, various technological solutions are used, which are distinguished by their high cost and technological difficulties in their application.

2. The technology of mechanical activation of the working solution has been developed, which makes it possible to increase its chemical activity and is characterized by low capital and operating costs.

3. To activate the leaching solution, it is proposed to carry out mechanical treatment only with sulfuric acid before the additional strengthening of the mother liquor. Comparison of the results of measurements of the uranium content in solutions upon activation of only water and only sulfuric acid showed that the activity increased by 14%. Consequently, under industrial conditions, there is no need to carry out mechanical activation of the entire leaching solution; it should be limited only to the activation of re-strengthening concentrated sulfuric acid. Thus, the volume of the solution to be treated and the costs of manufacturing and operating the activator are reduced.

4. The dependences of the uranium content in the productive solution on the degree of activation of the working solution and the time after activation have been obtained, which will allow regulating the degree of activation of the solution depending on the distance of its transportation. For example, activation of the solution leads to an increase in the content of the useful component in the productive solution from 9 to 21% and its activity persists for a long time (up to 30 days).

5. When conducting studies with non-activated and activated solution, the density of the leaching solution changes slightly, which does not affect the gravitational lowering of the productive solution.

6. To apply this technology under production conditions, an activator was manufactured and installed in block 8-9-3 of the Central Mynkudyk mine, the actual increase in the uranium content in the productive solution was 8%.

7. The expected economic effect is calculated taking into account the reduction in the consumption of sulfuric acid due to the reduction of the block's reserves mining period under the conditions of using the leaching solution activation technology. For one technological unit with a uranium reserve of 278.7 tons, the effect will be 25,426,192 tenge.