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# ILMIY AXBOROTNOMA

## НАУЧНЫЙ ВЕСТНИК
## SCIENTIFIC JOURNAL

## ANIQ VA TABIIY FANLAR SERIYASI

Matematika, Mexanika, Informatika
Fizika, Kimyo, Biologiya, Geografiya

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**Obuna indeksi** – yakka tartibdagi obunachilar uchun **- 5583,**
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**M U N D A R I J A**
**C O N T E N T S**


| № | Maqola nomi | Article title | Bet/ page |
|---|---|---|---|
| **1** | Kasr psevdoparabolik tenglama uchun Samarskiy-Ionkin ikki nuqtali chegaraviy shartlar<br>**Sagdullaeva M.U., Xasanov G.A., Yuldashev T.K.** | Samarskii-Ionkin two-point boundary conditions for a fractional pseudoparabolic equation<br>**Sagdullaeva M.U., Khasanov G.A., Yuldashev T.K.** | **5-14** |
| **2** | Gerasimov-Kaputo turidagi kasr tartibli nochiziqli differensial tenglamalar<br>**Shukurova M.D., Xasanov G.A., Yuldashev T.K.** | Nonlinear differential equation with Gerasimov-Caputo type fractional operator and degenerator<br>**Shukurova M.D., Khasanov G.A., Yuldashev T.K.** | **15-22** |
| **3** | NaH da lazer ta'sirida dissotsiatsiya dinamikasi<br>**Umarov O., Jumabaev A.** | Laser-induced dissociation dynamics in NaH<br>**Umarov O., Jumabaev A.** | **23-30** |
| **4** | Radon transformasidan foydalanish, tasvirni tanishda aylana sfera proyeksiyasini yaratish<br>**Khatamov O., Mamanova B.** | Using the radon transform to create a projection of a circular sphere in image recognition<br>**Khatamov O., Mamanova B.** | **31-38** |
| **5** | Flavonoid komplekslarining metal ionlari bilan sintezi, spektroskopik tadqiqotlar va supramolekulyar tizimlar<br>**Ergashova Sh., Muxamadiyev N.** | Synthesis of flavonoid complexes with metal ions, spectroscopic studies and supramolecular systems<br>**Ergashova Sh., Mukhamadiev N.** | **39-45** |
| **6** | 2-benzil-6,7-dimetoksi-1,2,3,4-tetragidroizoxinolin hosilalari sintez reaksiyalarini o'rganish<br>**Suyunova S.N., Quljonov J.X., Xudoyberdiyeva A.A., Urunbayeva Z.E. Z.E., Saidov A.Sh., Vinogradova V.I.** | Study of the reactions of synthesis of 2-benzyl-6,7-dimethoxy-1,2,3,4-tetrahydroisochinoline derivatives<br>**Suyunova S.N., Kuljonov J.X., Khudoyberdieva A.A., Urunbaeva Z.E. Z.E., Saidov A.Sh., Vinogradova V.I.** | **46-50** |
| **7** | Keyingi qo'shni tugunlargacha o'zaro ta'sirlanuvchi ikki bozonli panjara gamiltoniani<br>**Axmadova M., Axmatova Sh.** | A two-boson lattice hamiltonian with interactions up to next-neighboring sites<br>**Akhmadova M., Akhmatova Sh.** | **51-58** |
| **8** | Sekin aylanishli magnitlangan neytron yulduzlarning plazma magnitosferasi o'zgartirilgan gravitatsiyada<br>**Sayfiyev Sh.** | Plasma magnetosphere of slowly rotating magnetized neutron stars in modified gravity<br>**Sayfiev Sh.** | **59-65** |
| **9** | Vaqtli qatorlar va mashinaviy o'qitish asosida sotuvdagi kechikishlarni aniqlash usullari<br>**Nazarov F., Sayidqulov A.** | Methods for detecting delays in sales based on time series and machine learning<br>**Nazarov F., Sayidkulov A.** | **66-71** |
| **10** | Integrallashgan matematik modellar va ularning qo'llanilishi<br>**Safarov R., Xudoyberdiyev S.I.** | Integrated mathematical models and their applications<br>**Safarov R., Khudoyberdiyev S.I.** | **72-77** |
| **11** | Chekli zichlikka va qator ko'rinishdagi moslangan manbaga ega Hirota tenglamasi uchun boshlang'ich qiymat masalasi<br>**Eshbekov R.** | The initial value problem for the Hirota equation with finite density and self-consistent series source<br>**Eshbekov R.** | **78-84** |
| **12** | L-sistein bilan modifikatsiyalangan mezog'ovak silikagel yordamida og'ir metall kationlarini ajratish<br>**Ulugboyeva G.O., Kuliboyeva N.Sh., Uzokov J.R., Fazliyeva N.T., Muxamadiev N.Q.** | Removal of heavy metal cations using mesoporous silicagel modified with L-cysteine<br>**Ulugboeva G.O., Kuliboeva N.Sh., Uzokov J.R., Fazlieva N.T., Mukhamadiev N.Q.** | **85-90** |
| **13** | Titan nano oksidi sintezi va uning fotokatalitik xossalarini zarracha o'lchamiga bog'liqligi<br>**Mamaziyeva S., Avazova N., Tashmatova R., Muxamadiev N., Muxamadiev A., Uzokov J.** | Synthesis of nano titanium oxide and dependence of its photocatalytic properties on particle size<br>**Mamazieva S., Avazova N., Tashmatova R., Mukhamadiev N., Mukhamadiev A., Uzokov J.** | **91-96** |
| **14** | $SrTiO_3$ nanozarrachalarini sintez qilish va ularning o'lcham-fotokatalitik xossalari<br>**Hayitova M., Baxranova M.A., Muxamadiyev N.Q.** | Synthesis of $SrTiO_3$ and its size-dependent photocatalytic properties<br>**Hayitova M., Bakhranova M.A., Mukhamadiyev N.Q.** | **97-102** |

| № | Maqola nomi | Article title | Bet/ page |
|---|---|---|---|
| **15** | Rekreatsiya maqsadlarida tabiatdan foydalanishni boshqarish<br>**Rafikova N.** | Management of nature utilization for recreational purposes<br>**Rafikova N.** | **103-110** |
| **16** | Modifikatsiyalangan faollashgan ko‘mir yordamida eritma tarkibidagi organik bo‘yoqlarni ajratish<br>**Ergasheva D., Muxamadiyev A., Muxamadiyev N., Uzokov J.** | Separation of organic dyes from solutions using modified activated carbon<br>**Ergasheva D., Mukhamadiyev A., Mukhamadiyev N., Uzokov J.** | **111-116** |
| **17** | Neyron tarmoqli modellar asosida qandli diabetni tashxislashning intellektual algoritmlari<br>**Sariyev Sh.N.** | Intelligent algorithms for diagnosing diabetes mellitus based on neural network models<br>**Sariev Sh.N.** | **117-123** |
| **18** | Mahalliy kaolindan seolitlar sintez va fizik-kimyoviy tahlili<br>**Magdiev Sh., Majidova F., Nasimov A., Tashpulatov X., Toshpulatov D., Mirzayev Sh., Norboev K., Normuradov O.** | Synthesis and physicochemical analysis of zeolite from local kaolin<br>**Magdiev Sh., Majidova F., Nasimov A., Tashpulatov Kh., Toshpulatov D., Mirzaev Sh., Norboev K., Normuradov O.** | **124-129** |
| **19** | Densenet modelini transfer o‘qitish asosida masofadan zondlash sahnalarini tasniflash aniqligini oshirish maqolaning o‘zbek tilidagi nomi<br>**Yusupov O.R., Eshonqulov E.Sh.** | Enhancing the accuracy of remote sensing scene classification using transfer learning with densenet<br>**Yusupov O.R., Eshonkulov E.Sh.** | **130-144** |
| **20** | Neft va gaz quduqlari minerallashgan qatlam suvlarining kimyoviy tarkibi va fizik-kimyoviy xususiyatlarini o‘rganish<br>**Kenjaev N.A., Igamkulova N.A.** | Chemical composition and physico-chemical properties of mineralized formation waters from oil and gas wells<br>**Kenjaev N.A., Igamkulova N.A.** | **145-148** |

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# CHEMICAL COMPOSITION AND PHYSICO-CHEMICAL PROPERTIES OF MINERALIZED FORMATION WATERS FROM OIL AND GAS WELLS

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**Abstract.** This study investigates the chemical and physico-chemical properties of formation waters from several oil and gas fields in Uzbekistan, including Aral-4, Seul, Balkan, Berdakh, and Surgil. The research highlights the high concentrations of sodium and calcium ions, confirming that the studied waters belong to the hard water category. The composition of anions such as chloride ($Cl^-$), sulfate ($SO_4^{2-}$), carbonate ($CO_3^{2-}$), and bicarbonate ($HCO_3^-$) was also analyzed.

Electrochemical and ion-plasma methods were applied to alter the characteristics of mineralized formation waters, leading to changes in parameters such as rN (oxidation-reduction potential), density, viscosity, and ion composition. Experiments demonstrated that water could be converted into an acidic active solution without the addition of external chemicals, depending on applied voltage and electrode properties.

**Keywords:** formation water, physico-chemical properties, mineralized water, sodium ions, calcium ions, hardness, oxidation-reduction potential (rn), electrochemical treatment, ion-plasma method, anion composition.

## Neft va gaz quduqlari minerallashgan qatlam suvlarining kimyoviy tarkibi va fizik-kimyoviy xususiyatlarini o‘rganish

**Annotatsiya.** Mazkur maqolada O‘zbekistonning Aral-4, Seul, Bolqon, Berdax va Surg‘il kabi neft va gaz konlaridan olingan qatlam suvlarining kimyoviy va fizik-kimyoviy xossalari o‘rganiladi. Tadqiqot natijalariga ko‘ra, kationlar orasida natriy va kalsiy ionlari ustunlik qiladi, bu esa barcha suv namunalarining qattiq suvlar turiga mansubligini tasdiqlaydi. Shuningdek, xlorid ($Cl^-$), sulfat ($SO_4^{2-}$), karbonat ($CO_3^{2-}$) va gidrokarbonat ($HCO_3^-$) kabi asosiy anionlarning miqdori aniqlanadi.

Elektrokimyoviy va ion-plazmali usullar yordamida minerallashgan suvlarning rN ko‘rsatkichi, zichligi, qovushqoqligi va ion tarkibi o‘zgartirildi. Tajribalarda hech qanday kimyoviy modda qo‘shilmagan holda suvning kislotali faol eritmaga aylanishi kuzatildi. Hosil bo‘lgan cho‘kma tarkibi temir tuzlari asosida ekanligi rentgen-luminessensiya tahlili orqali tasdiqlandi.

**Kalit so‘zlar:** qatlam suvlari, fizik-kimyoviy xossalar, minerallashgan suv, natriy ionlari, kalsiy ionlari, qattiqlik, oksidlanish-qaytarilish potentsiali (rN), elektrokimyoviy ishlov, ion-plazmali usul, anion tarkibi.

## Изучение химического состава и физико-химических свойств минерализованных пластовых вод нефтяных и газовых скважин

**Аннотация.** В данной статье будут изучены химические и физико-химические свойства пластовых вод,

добываемых на нефтяных и газовых месторождениях Узбекистана Арал-4, Сеул, Балканы, Бердах и сургил. Исследование показало, что среди катионов преобладают ионы натрия и кальция, что подтверждает принадлежность всех проб воды к типу жесткой воды.ннотация. В данной статье будут изучены химические и физико-химические свойства пластовых вод, добываемых на нефтяных и газовых месторождениях Узбекистана Арал-4, Сеул, Балканы, Бердах и сургил. Исследование показало, что среди катионов преобладают ионы натрия и кальция, что подтверждает принадлежность всех проб воды к типу жесткой воды. Также определяются количества основных ,онов, таких как хлорид ($CL^-$), сульфат (so ,$2^-$), карбонат (со ,$2^-$) и бикарбонат (HCO,-).

Электрохимическими и ионно-плазменными методами изменялись pH-показатель, плотность, вязкость и ионный состав минерализованных вод. В экспериментах наблюдалось превращение воды в кислый активный раствор без добавления каких-либо химических веществ. С помощью рентгенолюминесцентного анализа было подтверждено, что состав образовавшегося осадка основан на солях железа.

**Ключевые слова:** пластовые воды, физико-химические свойства, минерализованная вода, ионы натрия, ионы кальция, твердость, окислительно-восстановительный потенциал (pH), электрохимическая обработка, ионно-плазменный метод ,уонный состав.

**Introduction.** In the modern world, the oil industry causes significant harm to the environment, as oil products and reservoir waters pollute the surrounding environment. These contain oil hydrocarbons, various salts, and mechanical impurities, which are absorbed by the soil and seep into groundwater, drastically altering their chemical and physico-chemical properties – such as salt composition, alkalinity, soil suspension reactions, soil absorption complexes, carbon-nitrogen balance, and disrupting the water-air regime. That is, the volume of formation waters is increasing in the process of oil and gas extraction and production.

One of the key sectors in the development of the Republic's economy is the oil and gas industry, along with the metallurgy of non-ferrous, precious, and rare metals. However, it should be noted that the reserves of non-ferrous, precious, and rare metals in the Republic are relatively limited. With the development of hydro-mineral raw materials, it is possible to create innovative production capacities for the extraction of lithium, iodine, bromine, strontium, and their elements and compounds from formation waters. Moreover, the main advantage of using industrial waters as a source of rare elements is the low cost of the products, since the brines of reservoirs have relatively high technological efficiency, and the extraction of rare elements does not require expensive mining[1].

The intensive extraction of many useful minerals has led to a significant reduction in the reserves of some rare elements, and due to the expansion of their use in new branches of engineering and technology, the demand for them has sharply increased. It should be emphasized that the formation waters in the saline areas of the Republic's oil and gas fields contain industrially significant amounts of mineral salts, micro-components (iodine, bromine), and rare metals (Cs, K, Sr, Ge, Sc, W, Mo, Au, etc.). However, as of today, the Republic lacks effective technologies for the extraction of these micro-components, mineral salts, and especially rare metals. The intensive extraction of many useful minerals has led to a significant reduction in the reserves of some rare elements, and the growing need for them is due to their increasing application in new sectors of engineering and technology[2]. With the development of hydro-mineral raw materials, it becomes possible to create innovative production capacities for extracting lithium, iodine, bromine, strontium, and other elements and their compounds from formation waters. Moreover, one of the main advantages of using industrial waters as a source of rare elements is the low cost of the final product. This is due to the relatively high technological efficiency of formation waters, which allows the extraction of rare and precious metals without the need for expensive mining operations.Among rare metals, lithium is widely used.

The global reserves of lithium raw materials are estimated at 13 million tons, with a global consumption of around 65 thousand tons. Of the proven lithium reserves, 22% are found in pegmatite ores, while 78% are found in various types of hydro-mineral raw materials. Due to lower processing costs compared to producing lithium carbonate from hard rock ores, the key principles of processing available raw materials include:technological and simple methods of extracting the main promising components (lithium and magnesium) from formation waters.
Further processing into marketable products such as MgO for magnesium and LiOH for lithium [3].

The purpose of our research is to study the chemical composition and physico-chemical properties of formation waters, as well as their impact on soil cover and vegetation during flooding. Electrochemical treatment methods for formation waters and wells are known both in our country and abroad. In order to develop a new, efficient technology for extracting micro-components, mineral salts, and rare elements from the mineralized waters of the Republic's oil and gas fields, the composition of these reservoir waters has been identified[4].

A separation regime was developed that enables the removal of particles from formation water. Full precipitation was achieved at temperatures ranging from 18°C to 45°C. The reprocessing was carried out using alternating current at industrial frequencies with a current density of 0.5 – 1.5 A/cm², and treatment times ranging from 2 to 15 minutes. The electrode corrosion rate in electrolyte solutions was 0.12–0.25 g/cm³. After 2 hours of precipitation, the solution no longer contained suspended particles, and the lithium content remained at its initial level. For precipitation, a lime solution (with at least 300 g/dm³, and a density of 20 – 21 g/cm³) was used as the primary agent. Complete precipitation of magnesium ions was achieved when lime was present in 5 – 10% excess over stoichiometric amounts, and the pH value reached 10.8 –11.3.
The precipitate was removed via filtration. Magnesium was entirely absent from the filtrate, and lithium levels were in the range of 13.8 – 14.1 mg/dm³. Lithium losses with the precipitate amounted to 3.0 – 5.2%. [5]

Laboratory studies were conducted on waters from the Orol-4, Seoul, Balkon, and Sev reservoirs to extract $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$, and $Li^{+}$ ions. Table 1 shows the data on the Berdakh and Surgil fields, water hardness, hydrogen index (pH), density of formation waters, and the composition of micro-components in mineralized formation waters.

**Chemical Composition and Physico-Chemical Properties of Formation Waters**

| No | Name | Formation density | rN | Hardness mg/eq | Cation composition mg/ l | | | | Total hardness |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | $Na^{+}$ | $K^{+}$ | $Ca^{2+}$ | $Mg^{2+}$ | mg/l |
| **1** | Aral -4 | 1,09-1,1 | 6,1 | 465 | 20695 | 600 | 700 | 5229 | 122,82 |
| **2** | Seule | 1,07 | 5,3 | 124 | 12015 | 100 | 1560 | 559 | 100,16 |
| **3** | Balkan | 1,1-1,12 | 6,6 | 223 | 39971 | 400 | 540 | 2383 | 22,66 |
| **4** | Severn Berdax | 1-1,08 | 6,5 | 131 | 14338 | 80 | 1320 | 990 | 24,82 |
| **5** | Surgil | 1,07 | 5,6 | 127 | 13604 | 186 | 1340 | 780 | 11,6 |

Based on the data above, it can be concluded that in all studied formation water samples, sodium ($Na^{+}$) and calcium ($Ca^{2+}$) ions dominate among the cations. In terms of hardness, the highest value is observed in the Aral-4 field. Given the concentration of divalent ions, all studied samples fall into the hard water category (hardness > 6 mg-eq/l). There are two types of electrical treatment effects on mineralized waters: electrochemical and ion-plasma. Both provide a flow of electric and plasma-chemical reactions that contribute to changes in the chemical and physico-chemical properties of water. Characteristics of formation waters, including the oxidation-reduction potential (rN), are influenced by several factors: the voltage applied to the electrodes, treatment time, electrode material, water composition, and degree of mineralization.

Many studies explain the physico-chemical processes occurring in mineralized waters during electrochemical and ion-plasma treatment, including the interaction of reaction products with saturated porous media. However, changes in filtration properties of formations after electrochemical and ion-plasma water injection have not been sufficiently addressed. Modern laboratory methods were used in experimental studies to analyze mineralized waters and the composition of resulting active aqueous solutions, such as:
centrifugation, chromatography, X-ray diffraction analysis, laboratory modeling of water displacement of oil in core samples. Depending on the electrochemical module (ECM) parameters, electrode

materials, and water composition, active aqueous solutions with rN values ranging from 1.5 to 12.5 can be obtained. Experimental Procedure: samples of formation water were poured into a vessel, and electrodes with applied potential were inserted. Water temperature changes, gas release volume, current, and voltage were recorded. After each experiment, the rN value of the water was measured. Experimental Results: experiments showed that regardless of initial electrolyte concentration, applied voltage, or distance between electrodes, rapid heating of the electrolyte occurred along with gas emission.

In experiments with formation water samples:

Distance between electrodes: 0.5 cm

Volume of water: 500 $cm^3$

Electrode material: Copper

Water density increased from 1136 to 1139 $kg/m^3$

Viscosity increased from 1.51 to 1.57 sP (Stokes)

Depending on the composition of the formation water, electrochemical effects can lead to both an increase and a decrease in rN value. In waters with high chloride content, electrochemical treatment shifts the rN toward the acidic side. An increase in bicarbonate ions ($HCO_3^-$) is shown in Table 2.

**Chemical Composition of Formation Water Ions and Anions**

| **Water Sample** **Total g/l** | **$Sl^-$** | **$SO_4^{2-}$** | **$CO_3^{2-}$** | **$HCO_3^-$** |
|---|---|---|---|---|
| **Anion** | 111,6 | 0,41 | 11,948 | 0,18 |

The stand column was filled with formation water containing the anions $Cl^-$, $SO_4^{2-}$, $CO_3^{2-}$, and $HCO_3^-$, totaling 12,061 mg/l. The voltage applied to the reaction zone ranged from 5 to 65 V. X-ray luminescence analysis of the precipitate showed that the deposit mainly consisted of iron salts, formed as a result of anodic dissolution of the electrode material. The composition of oxidized metals in the precipitate was as follows:

Iron – 88.2%

Sodium – 4.6%

Manganese and copper – 0.3%

Silicon and chromium – 0.2%

Nickel and other metals – less than 0.1%

rN measurements indicated that the reservoir water transforms into an acidic active solution without the addition of external chemical reagents. Thus, the hydrogen index (rN) changed from an initial value of 7.5 to 6.4 after 55 minutes, and further to 4.5 after 171 minutes of treatment. As a result of such treatment, the density, viscosity, chemical composition, and other properties of the water undergo changes.

**Conclusion.** Based on the study of formation solutions from a number of oil and gas fields – Aral-4, Seul, Balkan, and Sev peninsula, as well as fields like Berdakh and Surgil – and through the analysis of water hardness, hydrogen index, reservoir water density, and established methods for extracting compounds from hydro-mineral raw materials, it was determined under laboratory conditions that:

Formation waters of mineralized reservoirs contain valuable micro-components.

There is potential for processing and extraction.

The presence of useful components is confirmed experimentally.

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