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ҚАЙЫРЫМДЫЛЫҚ ҚОРЫ
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«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ
«ХАЛЫҚ» ЖҚ

ХАБАРЛАРЫ

ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ
АКАДЕМИИ НАУК РЕСПУБЛИКИ
КАЗАХСТАН»
ЧФ «Халық»

N E W S

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OF THE REPUBLIC OF
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NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

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. Webof 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.

ЧФ «ХАЛЫҚ»

В 2016 году для развития и улучшения качества жизни казахстанцев был создан частный Благотворительный фонд «Халык». За годы своей деятельности на реализацию благотворительных проектов в областях образования и науки, социальной защиты, культуры, здравоохранения и спорта, Фонд выделил более 45 миллиардов тенге.

Особое внимание Благотворительный фонд «Халык» уделяет образовательным программам, считая это направление одним из ключевых в своей деятельности. Оказывая поддержку отечественному образованию, Фонд вносит свой посильный вклад в развитие качественного образования в Казахстане. Тем самым способствуя росту числа людей, способных менять жизнь в стране к лучшему – профессионалов в различных сферах, потенциальных лидеров и «великих умов». Одной из значимых инициатив фонда «Халык» в образовательной сфере стал проект Ozgeris powered by Halyk Fund – первый в стране бизнес-инкубатор для учащихся 9-11 классов, который помогает развивать необходимые в современном мире предпринимательские навыки. Так, на содействие малому бизнесу школьников было выделено более 200 грантов. Для поддержки талантливых и мотивированных детей Фонд неоднократно выделял гранты на обучение в Международной школе «Мирас» и в Astana IT University, а также помог казахстанским школьникам принять участие в престижном конкурсе «USTEM Robotics» в США. Авторские работы в рамках проекта «Тәлімгер», которому Фонд оказал поддержку, легли в основу учебной программы, учебников и учебно-методических книг по предмету «Основы предпринимательства и бизнеса», преподаваемого в 10-11 классах казахстанских школ и колледжей.

Помимо помощи школьникам, учащимся колледжей и студентам Фонд считает важным внести свой вклад в повышение квалификации педагогов, совершенствование их знаний и навыков, поскольку именно они являются проводниками знаний будущих поколений казахстанцев. При поддержке Фонда «Халык» в южной столице был организован ежегодный городской конкурс педагогов «Almaty Digital Ustaz.

Важной инициативой стал реализуемый проект по обучению основам финансовой грамотности преподавателей из восьми областей Казахстана, что должно оказать существенное влияние на воспитание финансовой грамотности и предпринимательского мышления у нового поколения граждан страны.

Необходимую помощь Фонд «Халык» оказывает и тем, кто особенно остро в ней нуждается. В рамках социальной защиты населения активно проводится работа по поддержке детей, оставшихся без родителей, детей и взрослых из социально уязвимых слоев населения, людей с ограниченными возможностями, а также обеспечению нуждающихся социальным жильем, строительству социально важных объектов, таких как детские сады, детские площадки и физкультурно-оздоровительные комплексы.

В копилку добрых дел Фонда «Халык» можно добавить оказание помощи детскому спорту, куда относится поддержка в развитии детского футбола и карате в нашей стране. Жизненно важную помощь Благотворительный фонд «Халык» оказал нашим соотечественникам во время недавней пандемии COVID-19. Тогда, в разгар тяжелой борьбы с коронавирусной инфекцией Фонд выделил свыше 11 миллиардов тенге на приобретение необходимого медицинского оборудования и дорогостоящих медицинских препаратов, автомобилей скорой медицинской помощи и средств защиты, адресную материальную помощь социально уязвимым слоям населения и денежные выплаты медицинским работникам.

В 2023 году наряду с другими проектами, нацеленными на повышение благосостояния казахстанских граждан Фонд решил уделить особое внимание науке, поскольку она является частью общественной культуры, а уровень ее развития определяет уровень развития государства.

Поддержка Фондом выпуска журналов Национальной Академии наук Республики Казахстан, которые входят в международные фонды Scopus и Wos и в которых публикуются статьи отечественных ученых, докторантов и магистрантов, а также научных сотрудников высших учебных заведений и научно-исследовательских институтов нашей страны является не менее значимым вкладом Фонда в развитие казахстанского общества.

С уважением,
Благотворительный Фонд «Халык»!

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PURIFICATION OF PRODUCED WATER AFTER MINING

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Abstract. The article presents the results of research on the purification of reservoir waters after underground borehole leaching of uranium and other minerals, and also studied the chemical, mineralogical and sorption properties of brown coal, sodium humate, benthic clay, shungite-containing aluminosilicates. According to the IAEA's data on uranium reserves in the subsurface, Kazakhstan shares the world championship with Australia. Moreover, 75.3 % of the republic's uranium reserves are concentrated in deposits belonging to the formation-infiltration type, located in the largest Shu-Sarys province on the Eurasian continent and suitable for mining by the method of underground borehole leaching (UBL). UL, which originated as an idea in the 50s of the twentieth century in the United States, is currently a recognized method of uranium mining. Since 1988, uranium has been mined in the Republic of Kazakhstan by this method. Laboratory studies conducted at the D. A. Kunaev. Institute of Mining on water purification from heavy metals have shown that natural materials such as bentonite clay, as well as derivatives. Intensive development of uranium deposits in Kazakhstan and an increase in production volumes in the next 15–20 years by the UBL method creates a problem of contamination of groundwater and surface waters with heavy metal ions and radionuclides. In acidic residual solutions, the pH reaches 1.5–3.0, sulfates, chlorides,

nitrates accumulate, the concentration of which is 6–10 times higher than the maximum permissible concentration (UBL) in drinking water, the concentration of aluminum and iron ions exceeds 3.0-5.0 times, lead and cobalt 30-50 times, and manganese 1,700 times.

Keywords: minerals, mining, water purification, clay, shungite

The article was prepared as part of grant funding for the scientific project "Technology for obtaining an adaptogen drug based on humates from coal and wild plant extracts to create sustainable vegetation cover at man-made sites (AP14871298).

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ЖЕРАСТЫ СУЫН ПАЙДАЛЫ ҚАЗБАЛАРДЫ АЛҒАННАН КЕЙІН ТАЗАРТУ

Жалғасұлы Нариман — Д.А. Қонаев атындағы Кен істері институтының «Экология және кен жұмыстарының қауіпсіздігі» бөлімінің меңгерушісі, т.ғ.д., проф., Халықаралық «Экология» академиясының академигі, Алматы қ., Абай даңғылы, 191
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Аннотация. Мақалада уран мен басқа да пайдалы қазбаларды жерасты ұңғымалық сілтісіздендіруден кейін қабат суларын тазарту бойынша зерттеулердің нәтижелері, сондай-ақ қоңыр көмірдің, натрий гуматының, бентонит сазының, құрамында шунгит бар алюмосиликаттардың химиялық, минералогиялық және сорбциялық қасиеттері зерттелген. МАГАТЭ деректері бойынша жер қойнауындағы уран қоры бойынша Қазақстан Австралиямен әлем біріншілігін бөліседі. Сонымен қатар, республиканың уран қорларының 75,3 %-ы Шу-Сарысу провинциясының Еуразия құрлығындағы ең ірі орналасқан және жерасты ұңғымалық сілтілеу (ЖҰС) тәсілімен өңдеуге жарамды қабаттық-инфильтрациялық үлгіге жататын кен орындарында шоғырланған. XX ғасырдың 50-ші жылдарында АҚШ-та идея ретінде пайда болған жерасты сілтілеу қазіргі уақытта уран өндірудің танылған әдісі болып табылады. 1988 жылдан бастап ҚР-да уран осы әдіспен өндіріледі. Д.А. Қонаев атындағы Кен істері институтында ауыр металдарды өндіруде суды тазарту бойынша зертханалық зерттеулер бентонит сазы сияқты табиғи материалдардың

қатынасуымен жүретіні зерттелді. Қазақстанда уран кен орындарын қарқынды игеру және жақын арада 15–20 жылда ЖҰС әдісімен өндіру көлемін ұлғайту жер асты және жер үсті суларының ауыр металл иондарымен және радионуклидтермен ластану проблемасын тудыратыны белгілі. Қышқыл қалдық ерітінділерінде ЖҰС pH 1,5–3,0-ге жетуімен қатар, сульфаттар, хлоридтер, нитраттар жиналады, олардың концентрациясы ауыз суда шекті рұқсат етілген мөлшерден (ШРК) 6–10 есе, алюминий мен темір иондарының концентрациясы 3,0–5,0 есе, қорғасын мен кобальт 30-50 есе, ал марганец тіпіті 1700 есе асады.

Түйін сөздер: пайдалы қазбалар, өндіру, суды тазарту, саз, шунгиттер

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ОЧИСТКИ ПЛАСТОВЫХ ВОД ПОСЛЕ ДОБЫЧИ ПОЛЕЗНЫХ ИСКОПАЕМЫХ

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Аннотация. В статье приводится результаты исследований по очистке пластовых вод после подземного скважинного выщелачивания урана и других полезных ископаемых, а также изучены химические, минералогические и сорбционные свойства бурого угля, гумата натрия, бентовиновой глины, шунгитсодержащих алюмосиликатов. По данным МАГАТЭ по запасам урана в недрах, Казахстан с Австралией делит первенство в мире. Причем 75,3 % запасов урана республики сосредоточено в месторождениях, относящихся к пластово-инфильтрационному типу, расположенных в крупнейшей на Евразийском континенте Шу-Сарысуской провинции и пригодных для отработки способом подземного скважинного выщелачивания (ПСВ). ПВ возникшее как идея в 50-х годах XX-века в США в настоящее время является признанным методом добычи урана. С 1988 г. в РК уран добывается этим способом. Проведенные в ИГД им. Д.А. Кунаева лабораторные исследования по очистке вод от тяжелых металлов показали, что природные материалы, такие как бентонитовая глина, а также производные из угля и шунгитсодержащих алюмосиликатов могут быть применены для очистки пластовых вод после завершения добычи полезных ископаемых. Интенсивная разработка месторождений урана в Казахстане и наращивание объемов добычи в ближайшее 15–20 лет способом ПСВ создает проблему загрязнения подземных и поверхностных вод ионами тяжелых металлов и радионуклидами. В кислых остаточных растворах ПСВ pH достигает 1,5–3,0, накапливаются сульфаты, хлориды, нитраты, концентрация которых в 6–10 раз превышает предельно допустимую (ПДК) в питьевой воде, концентрация ионов алюминия и железа превышает в 3,0–5,0 раз, свинца и кобальта в 30-50 раз, а марганца в 1700 раз.

Ключевые слова: полезные ископаемые, добыча, очистка воды, глина, шунгиты

Introduction

The long-term strategy of the republic provides for the solution of one of the tasks - the restoration of disturbed natural ecological systems in the region of intensive mining. In Kazakhstan, which has a powerful raw material base of uranium, oil and coal, the complex hydro-ecological situation is predetermined by a number of natural man-made factors, including: the widespread distribution of natural ground and underground waters with a high content of radionuclides and heavy metals, the presence of a large number of foci of contamination in the form of radioactive dumps rocks and water discharges during geological exploration and exploitation work at mineral deposits. In the process of operation, a mining enterprise certainly disrupts the eco-balance in the region, and in particular, the most vulnerable underground hydraulic system, which leads to changes in hydrochemical conditions and the quality of groundwater. In the production provinces of uranium mining, one can observe a high content of radionuclides and heavy metal ions.

The same excess of MPC is observed for other microelements. In terms of the amount of dissolved salts, they are in most cases brackish or saline, and due to the epigenetic processes of the formation of uranium polyelement ore deposits, they always contain environmentally hazardous concentrations of stable elements (selenium, arsenic, bromine, fluorine, iron, manganese, chromium, vanadium and molybdenum, etc.) (Zabaznov, 2004).

The recommended materials, according to the research data, have a fairly high sorption capacity and, in addition, the deposits of these sorbents are located in close proximity to the ISR sites. This is an important factor in the economic assessment of the developed technology, since transportation is the most expensive expense item. Fossil brown coal was studied, as well as one subjected to pyrolysis to remove volatile components and activate the surface, and humic preparations from brown coals.

Brown coal from the Kiyakta deposit (Ulytau region, Kazakhstan) contains up to 60–70 % humus, up to 30% amorphous silica, and the pH of the water extract does not exceed 6.7–7.0. From these data it follows that the introduction of coal into formation waters will reduce the acidity of the environment, and the presence of a significant amount of humic compounds, which exhibit a tendency to ion exchange, the formation of strong complexes with heavy metals, and redox reactions, determines the versatility of this natural sorbent. In addition, the presence of amorphous silica, which has well-developed porosity and reactivity, enhances the sorption properties of brown coal. Sodium humate was obtained using known technology from brown coal and biolayer (Zabaznov et al., 2001).

An analysis of the mineralogical composition of the clay from the Shukuroi deposit showed that it mainly represents a genetic mixture of montmorillonite (65–75 %) and hydromica; muscovite, biotite, and kaolinite are found in small quantities as impurities (no more than 5 %). It is known that the cation exchange ability of clays is mainly due to the presence of montmorillonite in them and is determined by the sum of exchangeable ions of sodium, calcium, magnesium, hydrogen and aluminum (Zhalgasuly et al., 2018).

Shungite-containing aluminosilicates of the Kok-Su deposit are mainly represented by silicon oxide (40–70 %), and their content of carbon and mineral components is 6–12 %, about 5 % aluminum oxide, potassium and sodium 0.4–1.5 %. They are silicate rocks of quartz-serecite schists with a layered shungite structure. The presence of a large amount of silicon, exchangeable sodium and potassium cations, as well as a layered structure predetermine the possibility of using them as a sorbent to reduce the salinity of formation waters (Zhalgassuly et al., 2020).

A unique feature of Kazakhstan's uranium reserves is that 75 % of them are concentrated in deposits associated with regional zones of reservoir oxidation. This type of deposit is not widespread in the world. In the Republic, these deposits are concentrated mainly in the Shu-Sarysu, Syrdarya and Ili uranium ore provinces.

With IBL uranium, the release of radioactivity into the atmosphere is significantly lower than with traditional mining methods of mining and processing uranium ore. Wells filled with liquid throughout the entire period of operation prevent the release of radon from the subsurface. During borehole leaching, only about 20 % of the main radioactive elements enter a mobile state in the subsurface and are brought to the surface, compared to 100% with traditional mining methods. There is also no need to build tailings storage facilities with a high level of radiation from the stored material. Solutions coming from leaching sites have a low level of radiation as a result of the poor solubility of radium and short-lived daughter products of the decay of U-238; only a very small part of Ra-226 and other radionuclides of the uranium-radium series is sorbed on the ion exchange resin simultaneously with uranium. In addition, groundwater near and within the contours contains elevated concentrations of Ra-226.

The virtual absence of disturbances and surface contamination allows the land to be returned for further use in a short time. The main problem of environmental protection during borehole uranium mining comes down to preventing contamination of groundwater, this problem is especially relevant when the ore-bearing aquifer or adjacent aquifer serves as water use objects.

Significant amounts of sulfates, chlorides, bicarbonates, iron, aluminum, nitrates, radionuclides and other trace elements accumulate in IBL solutions. Contamination of groundwater with these solutions can occur in the event of their significant spreading beyond the boundaries of exhausted deposits or individual deposits along ore-bearing and adjacent aquifers. The ingress of hazardous components into drinking water can lead to serious environmental consequences. Hence, the rehabilitation of groundwater from residual technological solutions of IBL is one of the main and urgent tasks of mining.

Materials and basic methods

Ways and methods of aquifer reclamation. As a result of the research, the sorption capacity of each sorbent was determined. The sorption capacity of the studied sorbents in laboratory conditions was determined with a particle size distribution of coal of class up to 5 mm, in the range of 0.1–0.05 mm, and of bentonite clay from 0 to 1 mm. Under these conditions, the amount of natural sorbent required to purify 1 liter of residual solution was calculated using the formula:

$$q_{п.с.} = \frac{\Sigma C_{ост.} - \Sigma C_{пдк}}{N}, г \qquad (1)$$

where is the total concentration of harmful components in the residual solution, mg/l;

ΣSpdk – the total concentration of harmful components according to the maximum permissible concentration for drinking water, which is 1000 mg/l;

N - maximum sorption capacity of natural sorbent, mg/g.

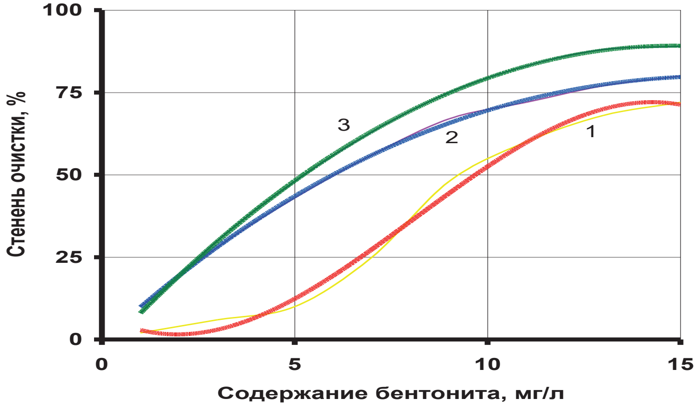
From practical data it follows that the total mineralization of residual solutions after IPS can reach 17,000–30,000 mg/l.

Thus, the total amount of impurities that must be neutralized to the permissible limit (MPC) reaches 16,000–29,000 mg/g.

Laboratory studies have established that the sorption capacity for the sum of components reaches 24.13 mg/g for bentonite clay and 24.16 mg/g for pyrolyzed brown coal. To neutralize impurities contained in 1 liter of residual solution, it is necessary to introduce from 540 to 1208.3 g of sorbent. That is, according to the calculation results, the T:W ratio will be close to 1:1¸1:2. Under the condition of one-time injection of the sorbent into the formation, its state of aggregation will be close to paste-like. In this case, certain difficulties will be created, such as movement along highways, and if the pumping unit fails, given the tendency of bentonite clay to swell, a thick gel will form, which will be difficult to pump into the formation.

In this regard, it is necessary to reduce the mass of the sorbent, which can be achieved by increasing its activity. It is known that substances in a finely dispersed state become more chemically active. Purely physical grinding processes associated with the application of mechanical forces cause chemical reactions or changes in reactivity. Mineral substances activated by grinding are characterized by high sorption capacity, and mechanical activation stimulates the emission of electrons, increasing the free surface of the substance. Since the reactivity and sorption capacity increases due to mechanical activation, the amount of sorbent can be significantly reduced. This reduces the viscosity of the suspension, facilitating the process of moving them along the line to the pump and further into the formation.

As studies have shown, based on the sorption of heavy metals and sulfate ion from model solutions with bentonite clay from the Shukuroi deposit and pyrolyzed brown coal crushed to a particle size of 25 microns, it has been established that the optimal amount of bentonite and coal for the sorption of heavy metals can be 15 mg/l. At the same time, the degree of purification for lead, copper and zinc is 83–92 %, 98.8–80 %, 72–66 %, respectively, and the concentration of sulfate ions is reduced to 33.8–37.3 % (Figure 1).



1-lead, 2-zinc, 3-copper

Figure 1 – Dependence of the degree of purification of solutions from heavy metals

One of the representative objects in this case is the Dzhidinsky tungsten-molybdenum plant, located in the Republic of Buryatia, which is a dangerous source of environmental pollution precisely due to the significant amount of waste accumulated in the dumps and tailings, including hazard classes II and III.

They are intensively oxidized, leached and destroyed, which leads to a change in the mineralogical and material composition of technogenic deposits, the removal of elements and the formation of dispersion halos around the dumps. As a result, the tailings obtained as a result of ore processing do not correspond to the original composition of the enriched material (Fedotov et al., 2016).).

The choice of reclamation methods is determined, first of all, by the method of using various solvents: sulfuric acid (experience of the CIS countries, partly the USA) or carbonate (US experience), and possible methods of water purification are divided into artificial and natural.

Rehabilitation of groundwater purification is carried out due to external influences - activities associated with pumping, injection of solutions of a certain composition, processing them on the surface with or without the addition of chemical reagents. Natural restoration of horizons is based on the use of more extensive, but more reliable natural processes, such as the action of the natural flow of groundwater delineating the mined area, dispersion (dispersion), sorption phenomena in the subsurface, etc. Various combinations of natural and artificial recovery methods are also possible.

If the geological environment does not have the initial and residual resources for self-healing or there is a need to rehabilitate the quality of groundwater in the shortest possible time, then it is necessary to resort to artificial treatment methods.

The first group involves the extraction of residual solutions from the subsurface and their purification from harmful substances on the surface. In this case, the entire arsenal of chemical technology methods is used - sorption on ion-exchange resins, extraction, electrodialysis, flotation and freezing, concentration by evaporation and many others. These methods are extremely expensive; recycling of individual valuable components does not compensate for all costs. At the same time, significant masses of non-recyclable harmful substances accumulate on the surface (tens and hundreds of tons from one waste disposal site). According to VNIIPromtekhnolog, the costs of restoring the quality of groundwater using the specified methods in the cost of the final product range from 17 to 50 %.

The second group of methods is focused on neutralizing solutions directly in the subsurface. The following techniques are used here: displacement of residual solutions with compressed air into the surrounding rocks and electrochemical methods of in situ cleaning; neutralization of solutions at the site of occurrence with soda; reduction of U, As, Se and Mo with sodium sulfite solutions; microbiological methods of purification by introducing natural microflora cultivated on the surface into ore-bearing horizons; pumping residual solutions from the ore-bearing horizon to underlying horizons with high neutralizing and reducing capacity of the lithological environment, etc. Below is a brief description of the main methods and results of their use for the rehabilitation of groundwater.

The method of washing in the subsoil in relation to the sulfuric acid method. The ISV method of washing has been studied in laboratory conditions and partially tested in a pilot scale at the Uvanas field in Kazakhstan.

The most representative data on the use of this method were obtained at block No. 50. 13 wells with an average flow rate of 2.5 m3/hour were involved in pumping out residual solutions. During six months of experiment, about 140 thousand m of solutions were pumped out, which amounted to about 1.5 pore volumes of the block. During this period, pH values increased in the western part of the block from 1.3 to 1.6, in the central part - from 1.7 to 1.9. At the same time, the amount of residual sulfuric acid in the western part remained practically unchanged and remained at the level of 2.6 g/l, in the central part it decreased by half (from 1.7 g/l to 0.8 g/l) and in the eastern part - from 1 .7 g/l to zero.

The displacement of residual solutions with compressed air was also tested at the pilot site of the Uvanas field. The experimental block was circular in shape with a radius of 50 m, the thickness of the productive horizon was about 10 m, the active porosity was 0.2, and the total mineralization of residual solutions was 23 g/l. Air was pumped into 6 wells with a total average flow rate of 600=700 m3/hour, residual solutions were pumped out from three wells located in the center of the site, with a total average flow rate of 6÷8 m3/hour. During the experiment, control was carried out over the air flow through injection wells, solution flow rates, groundwater level and the position of the air-solution interface in the contour of the experimental area. During 150 days of air injection, about 10 thousand m of residual solutions were simultaneously pumped out, which amounted to more than 85 % of the pore volume of the area.

The method of reagent purification of residual solutions on the surface involves the construction of a complex of chemical production facilities for reagent precipitation of components of contaminated water. With one of the chemical methods - liming - solutions are purified from iron, aluminum and a group of ions that can co-precipitate with the corresponding hydroxides. The mineralization of the solution after liming is reduced to 2÷6 g/l and is mainly determined by the presence of calcium sulfate in the solution. The processing of the suspension formed during liming is carried out by flotation, since the thickening process under these conditions is ineffective due to poor compaction of hydroxides. Solid waste obtained after vacuum filtration must be buried because it contains radioactive components.

After filling with sludge, such storage ponds are backfilled. The change in the composition of solutions after chemical retraining and after electrodialysis processing is shown in Table 1.

Table 1- Change in the composition of solutions after electrodialysis processing of various metals

Определяемый компонент	Остаточный сернокислый раствор, мг/л	Раствор после химической обработки, мг/л	Дилюат, мг/л
Калий	160	150	1,46÷5,8
Натрий	860	3500	135÷465
Кальций	452	440	1,6÷3,2
Магний	700,8	655	н.о
Железо общее	568,1	Н.о	н.о
Аммоний	37,5	35,7	н.о
Алюминий	729	н.о	н.о
Сульфат	10560	9360	120,6÷577,7
Хлорид	307,9	183	10,0÷18,4
Нитрат	650	590	9,4÷27,0
pH	2,25	10,5	9,25÷9,9
Общая минерализация	15025	14914	278÷1100

The composition of the diluate obtained using precipitation-electrodialysis technology, shown in the table, shows the deep demineralization of residual EPS solutions and their suitability for domestic and drinking water supply.

A similar method of reagent purification of solutions was used in industrial conditions in Czechoslovakia at the Straž deposit. Station productivity 3 m/min, initial total mineralization of residual solutions 6÷7 g/l. Purified water containing sulfates up to 2 g/l and nitrates up to 50 mg/g was discharged into the river network. The solidified sludge was fed to the tailings dump of GMZ Gamr. The cost of cleaning under these conditions exceeds those above by 3–4 times (Roshal et al., 1979; Liu Zhu et al., 2023).

Taking into account the above, when preparing natural sorbents for the introduction of a layer in the form of a suspension, we studied the grinding process and determined the dependence of the particle size distribution on the grinding time; the selection of the optimal T:L ratio was carried out to obtain a stable suspension; The activity of the crushed sorbent was studied.

From the above brief review of existing methods for rehabilitating aquifers after uranium ISR, it follows that for a number of objective reasons, no country using this mining method has yet specifically defined any of these methods or their complex. The legislative component of this problem has not been fully developed.

At the same time, we have to admit that all these technologies, unfortunately, are difficult to implement, require significant costs and are not effective enough, since in the end they again involve the construction and maintenance of solid radioactive waste storage facilities. The costs of groundwater restoration using these methods range from 20 to 50 % of the cost structure of the final product.

Therefore, the author of this work has made an attempt, based on a generalization of some published materials, as well as data from his own research, to determine the place of the hydrogeochemical method of aquifer rehabilitation in this serious issue.

Results and discussion

Specific surface area is one of the most important physicochemical characteristics of sorbents. It was determined by the acetic acid adsorption method. Based on the results of the experiment, adsorption isotherms were constructed and the specific surface areas of the original coal, as well as the processed raw material, were calculated for 30 minutes. At the same time, an increase in the specific surface area was observed from 4.7 m2/g (initial coal) to 8.4 m2/g (mechanical treatment for 30 minutes) (Figure 2).

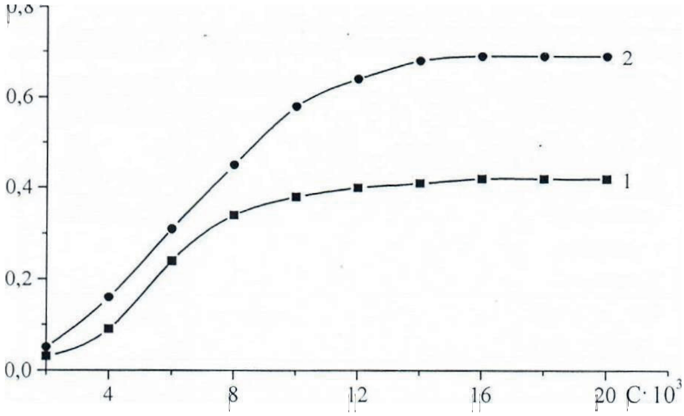


Figure 2 - Adsorption isotherm of acetic acid on coal
Kiyaktinskoye field

The results obtained show that during mechanical processing of coal, the specific surface area and potential increase, and therefore its sorption activity increases.

Numerous studies (Mohammad et al., 2019; Ablaeva et al., 2002; Jiménez et.al., 2018; Fayeq Abdel Hafez Al-Ajalin et al., 2020; Kudryashov et al.,2004) on the mechanical activation of mineral substances indicate that crushed substances are characterized by an increased supply of free energy, which to one degree or another depends on the method of influence on the crushed material and the rhythms of the grinding apparatus.

Since the activation of mineral substances largely depends on the type of grinding apparatus, an analysis of technical means was carried out from the point of view of their use as activators. The analysis showed that for grinding coal, the technical characteristics and capabilities of the RETSCH vibration mill and disk mill DM 200 meet the requirements.

The main advantage of the disc mill is the large initial particle size of the material with a side length of up to 200 mm and the final fineness of up to 100 μm, which can be achieved within a few minutes.

The crushed coal is then mixed with water or residual solution to be introduced into the formation. Laboratory studies conducted in 2016–2017, the results of sedimentation analysis, as well as experience with water-coal suspensions, showed that coal particles in suspensions tend to settle, which leads to stratification of the suspensions.

The results of studies with T:F ratios of 1:9; 2:8; 3:7; 4:6; 5:5; 6:4; 7:3; 8:2;, 9:1 are given in Table 2.

Table 2 – Results of studies to optimize the ratio of coal: water

Т:Ж	Агрегатное состояние	Время расслаивания	Т:Ж	Агрегатное состояние	Время расслаивания
1:9	Суспензия	>2 час	6:4	Влажная рыхлая масса	Не расслаивается
2:8	Суспензия	>2 час	7:3	Влажная рыхлая масса	Не расслаивается
3:7	Суспензия	>1 час	8:2	Почти сухой уголь	Не расслаивается
4:6	Суспензия	30 мин			Не расслаивается
5:5	Паста жидкая	Не расслаивается			

As follows from the results of the studies, at a ratio of 1:9 to 3:7, a fairly stable suspension is formed that does not separate within 1–2 hours.

Increasing the coal content to T:L 5:5 (1:1) leads to the formation of a pasty mass that is quite thick. This fact may call into question the possibility of its injection into the reservoir. A further increase in the solid phase changes its state of aggregation from a wet, loose mass to an almost dry state.

To determine the degree of homogenization and operating parameters of mixing, laboratory experiments were carried out to physically simulate mixing conditions (Table 3).

It should be noted that, ideally, mixing the components should lead to the formation of a homogeneous mixture, and the ratio of the components in any volume taken at different points of the mixer should be the same. In practice, deviations from ideal mixing conditions are always observed, the magnitude of which depends on factors such as:

- mixing method (fluidized bed mixing, pouring, etc.);
- features of the design of mixers and operating modes (degree of filling, speed and nature of material circulation, design of the working body, etc.);

- physical and mechanical characteristics of the mixture (ratio of components, particle size distribution, density of components, the possibility of their interaction during mixing.

Sampling was carried out at specified points. To do this, after stopping the mixer, samples were taken from different places in the body of the mixer using a special sampler. The weight of the sample taken was justified depending on the problem being solved. The smaller the sample weight, the more accurately the quality of the mixture can be characterized. However, it is impossible to reduce the weight of the sample excessively, since there comes a time when an excess or deficiency in the sample of one of the components, calculated in one or more particles, significantly affects the quantitative assessment of the mixing index.

A quantitative assessment of mixing using the mixer in question was carried out on model mixtures using the heterogeneity coefficient:

$$V = \frac{100}{m}\sqrt{\frac{\sum_{i=1}^{n}(x_i - m)^2}{n-1}}, \%,$$

where X; - i -th value of the parameter;

m - average value;

n - number of samples.

To determine possible stagnant zones of the mixer, we considered the process of mixing coal (fraction <2 mm) and granulated polyethylene, the granules of which differ sharply in shape and color from coal particles (Table 3). After mixing, the number of polyethylene granules in each sample was visually determined. Samples were taken from two extreme points from the bottom of the phase in the system that changes its state of aggregation from the wet mixer container, as well as two points in the upper and one central region of the mixer container.

The results obtained show that for bulk materials, homogeneous mixtures are obtained with mixing durations above 2 minutes. In industry, the quality of mixing is considered satisfactory if the heterogeneity coefficient does not exceed 20 %.

To determine the quantitative characteristics of the homogeneity of the mixture, an experiment was performed in which the coal in the mixer was irrigated with water through a nozzle. The amount of water introduced into the mixture corresponded to real conditions and amounted to 20 % of the mass of coal.

Table 3 - Dependence of the quality of mixing brown coal with polyethylene on mixing time

Время перемешивания, мин	Содержание гранул полиэтилена в пробах, штук					Коэффициент неоднородности, %
0,5	36	34	21	9	10	58,2
1	29	28	18	17	17	28,2
2	23	19	22	23	20	8,5
3	22	25	24	20	21	9,3

The experiments were carried out using brown coal from the Kiyakty deposit of fraction <2 mm, the homogeneity of the mixture was assessed based on the moisture content of the samples, determined according to the GOST 27314–91 method with rounding the result to a whole number.

The results obtained are presented in Table 4. The mixing time was counted from the moment the water was added, which was 3–5 minutes. As can be seen from the table data, a completely satisfactory degree of homogenization occurs already with three minutes of mixing coal with water.

Table 4 - Dependence of the quality of mixing brown coal with water on time

Время перемешивания, мин	Влажность смеси в пробах, %				Коэффициент неоднородности, %
1	51	31	40	22	34,4
2	29	30	41	46	22,9
3	34	38	35	39	6,5

The data obtained indicate the compliance of the mixer and the technological line as a whole with the goals and objectives of preparing sorbent from brown coal from the Kiyakty deposit.

Thus, from the results of the tests, the conclusion follows: coal grinding should be carried out either in a vibratory mill or a disk mill based on the principle of abrasion of the product for 15–30 minutes. Increasing the grinding time leads to aggregation of the smallest particles. The chemical activity of the sorbent crushed in this way reaches a maximum, as evidenced by the indicators ≤ potential and specific surface area of dispersed particles. The amount of water introduced varies from 50 % to 90 % and is determined by the operating parameters. Mixing time is 3–5 minutes. Preparation of a suspension of bentonite clay for injection into a clay reservoir for injection into a reservoir.

The rock-forming minerals of clays used for sorption are various minerals of the montmorillonite, hydromica, palygorskite and kaolinite groups. In practice, clay rarely has a monomineral composition; more often it contains several clay minerals. The base used for our bentonite clay research is montmorillonite.

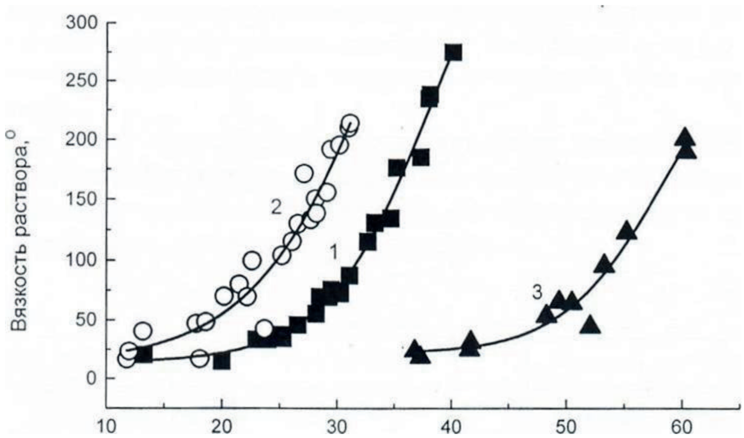
Chemically, clays are hydrated aluminosilicates. Each clay has a certain number of exchangeable ions. The most common clay minerals have the following exchange capacity: montmorillonite - 0.8–1.5; hydromica - 0.1–0.4; palygorskite 0.2–0.3 and kaolinite - 0.03–0.15 mol/kg (Ogata et al., 1961; Apblett et al., 2001; Xu Pan, Wang Wei-qiang et al., 2015).

When preparing a clay solution, the primary dispersion of the solid phase occurs. The dispersity of this phase depends on its properties, initial particle sizes, method and duration of grinding. Typically, complete dispersion does not occur during the cooking process. A significant mass of solid phase particles in the initial disperse system is aggregates of fine particles. Under the influence of loads, these aggregates are destroyed; due to the adsorption decrease in hardness and disjoining pressure, the material splits with the formation of smaller particles. As experiments have shown, there is a certain duration of the process, an increase in which no longer leads to further dispersion of solid particles and a change in the properties of the dispersed system.

o prepare clay solutions and evaluate their technological properties, the following clays were used: Tonkerian bentonite of two types, pink and green, and local clay from the Boraldai deposit.

The suitability of clay raw materials for preparing solutions was assessed in accordance with the requirements of the standard using a VSN-3 rotational viscometer. The tested clay was mixed using a mechanical propeller-type mixer for 20 minutes, kept for 16–20 hours, then mixed again in the mixer and the viscosity of the suspension was determined on a viscometer at a rotation speed of 600 min-1 (Figure 3).

As can be seen from the graph above, the viscosity of clay solutions largely depends on the nature of the clay and its chemical composition. Therefore, when preparing the sorbent for injection into the formation, it is necessary to determine the viscosity of the clay solution.



1 - Tonkerian No. 1; 2 - Tonkerian No. 2; 3 - local.

Figure 3 - Dependence of solution viscosity on clay content

An equally important step in the preparation of clay sorbent is the mixing process. Mixing dough-like materials represents an intermediate case between mixing in a liquid medium and mixing solid bulk substances. Very often, the same mixers are used for mixing viscous liquids and thin pastes as for low-viscosity Newtonian liquids, and some devices for mixing doughy masses are used for mixing solid bulk materials.

Taking into account the above, the clay was filled with water, kept for 1–2 days and then mixed in a mechanical propeller mixer for 10 minutes and the viscosity of the solution was measured on a VSN-3 viscometer. After obtaining satisfactory results, the solution was sent to the pipeline for injection into the reservoir.

The sorbent preparation unit satisfies the conditions obtained during the development of methods for the preparation of brown coal and bentonite clay sorbents. The results of the study on the preparation of clay sorbent showed that to obtain a suspension, it is enough to mix bentonite clays with water and leave them for 2 hours at a T:L ratio of 1:2 to 1:4. The "clay:water" ratio is determined, as already indicated, by the chemical and mineralogical composition of the clay, its tendency to swell and the viscosity of the solution. Experience with drilling fluids shows that the density of the clay fluid should not exceed 1.22 g/cm3, and the conditional viscosity should not exceed 60 s.

When characterizing technogenic changes during mining, the authors consider it important to emphasize that this technology, in general, only intensifies the natural processes of changing the phase state of matter due to a sharp change in the redox situation of the host hydrochemical environment. All elements passing into solution are initially present in the ore horizon in the solid phase. The amounts of sulfates (acid leaching) or carbonates (alkaline) introduced in this case are negligibly small compared to their natural volumes in the waters and rocks involved in the process of underground leaching. In other words, in this complex process there is no artificial technogenic pollution of the environment, but only an intensive impact on it (Grando et al., 2016; Cline et al., 1998; Grant et al., 2002; Fakhru'l-Razi et al., 2009).

Based on this, it becomes legitimate and logical to say that if such an impact is stopped, the natural redox processes of the aquifer will begin to be restored and, accordingly, the demineralization of groundwater will begin.

Conclusion

1. The sorption properties of previously unexplored organomineral rocks of deposits in Kazakhstan, brown coals, bentonite clays, and shale carbon-containing aluminosilicates were studied.

2. The chemical and sorption properties of oxidized brown coal from the Kiyakty deposit, which is prone to sorption of heavy metals, but does not purify water from sulfate ions, are assessed, which is explained by its chemical composition.

3. Bentonite clay from the Shukuroi deposit has high sorption properties with respect to both cations and anions and ensures purification of water from impurities up to 95 %.

4. The sorption properties of shale carbon-containing aluminosilicates were assessed, it was found that the sorption capacity of this sorbent is not large, but provides a degree of water purification of up to 40–70 %.

5. It has been established that sodium humate isolated from brown coal exhibits high chemical activity, reacts with heavy metal ions, and forms strong complex organometallic compounds. The formation of coagulants with impurity anions leads to a decrease in their concentration in water and the degree of purification reaches up to 95–98 %.

Concluding that the experiments performed allow us to conclude that the most effective natural sorbents among those studied are the biolayer of the Kiyakty deposit, brown coal subjected to pyrolysis and bentonite clay, and coals in their natural form do not absorb sulfate ions, and shungite-containing aluminosilicate shales also have low sorption capacity.

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