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# INVESTIGATION OF THE POSSIBILITY OF PRODUCING LIQUID GLASS BASED ON OPOKA FROM THE TASKALA DEPOSIT

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This paper examines the feasibility of producing liquid glass using a natural siliceous raw material - flake from the Taskala deposit, located in the West Kazakhstan region of the Republic of Kazakhstan. Physicochemical analyses of the source material were performed, determining its chemical and mineralogical composition, silica content, and clay content. Chemical composition revealed a $SiO_2$ content of 70-78%, which meets the raw material requirements for liquid glass production. The process of alkaline treatment of opoka using 20% solutions of sodium and potassium hydroxide has been studied. The temperature and time parameters affecting the completeness of silica dissolution have been studied. It has been established that at a temperature of 95-98 °C and a duration of 2-3 hours, the best result is achieved in terms of the yield of liquid glass with a silicate module within the regulatory limits when the raw material: alkali ratio is 1:2. Alkaline treatment of flasks using 20% sodium and potassium hydroxide solutions was studied. Temperature and time parameters influencing the completeness of silica dissolution were examined. It was found that a temperature of 95-98°C and a duration of 2-3 hours with a raw material: alkali ratio of 1:2 yielded the best liquid glass with a silicate modulus within the specified limits. Thus, the opoka from the Taskalinsky deposit can be effectively used as a raw material for the production of liquid glass, which has been confirmed by laboratory tests and a feasibility study of the process.

**Keywords:** liquid glass, opoka, siliceous raw materials, Taskalinskoye deposit, silicon dioxide, silicate module, sodium hydroxide, potassium hydroxide, chemical processing.

# ИССЛЕДОВАНИЕ ВОЗМОЖНОСТИ ПОЛУЧЕНИЯ ЖИДКОГО СТЕКЛА НА ОСНОВЕ ОПОКИ ТАСКАЛИНСКОГО МЕСТОРОЖДЕНИЯ

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В работе рассмотрена возможность получения жидкого стекла на основе природного кремнистого сырья - опоки Таскалинского месторождения, расположенного в Западно-Казахстанской области Республики Казахстан. Исследованы физико-химические анализы исходного материала: определены химический и минералогический состав, содержание кремнезёма и глинистых компонентов. Химический состав показал содержание $SiO_2$ на уровне 70-78%, что соответствует требованиям к сырью для получения жидкого стекла.

Изучен процесс щелочной обработки опоки с применением 20%-ных растворов гидроксида натрия и калия. Изучены температурно-временные параметры, влияющие на полноту растворения кремнезёма. Установлено, что при температуре 95-98 °С и продолжительности 2-3 часа в соотношении сырьё:щёлочь = 1:2 достигается наилучший результат по выходу жидкого стекла с силикатным модулем в пределах нормативных значений. Таким образом, опока Таскалинского месторождения может использоваться в качестве сырья для производства жидкого стекла, что подтверждено лабораторными испытаниями и технико-экономическим обоснованием процесса.

**Ключевые слова:** жидкое стекло, опока, кремнистое сырьё, Таскалинское месторождение, диоксид кремния, силикатный модуль, гидроксид натрия, гидроксид калия, химическая переработка.

## ТАСҚАЛА КЕН ОРНЫ ОПОКАСЫ НЕГІЗІНДЕ СҰЙЫҚ ШЫНЫ АЛУ МҮМКІНДІГІН ЗЕРТТЕУ

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Жұмыста Қазақстан Республикасының Батыс Қазақстан облысында орналасқан Тасқала кен орнының опокасы - табиғи кремний шикізаты негізінде сұйық шыны алу мүмкіндігі қаралды. Бастапқы материалдың физика-химиялық талдаулары жүргізіліп, оның химиялық және минералогиялық құрамы, кремний диоксиді және саз құрамы анықталды. Химиялық құрамы сұйық шыны өндірісіне қойылатын шикізат талаптарына сай келетін $SiO_2$ мөлшерінің 70-78% екенін көрсетті. Натрий мен калий гидроксидінің 20% ерітінділерін қолдана отырып, опоканы сілтілі өңдеу процесі зерттелді. Кремний диоксидінің еруінің толықтығына әсер ететін температура-уақыт параметрлері зерттелді. 95-98 °С температурада және 2-3 сағат ішінде шикізат:сілті = 1:2 қатынасында нормативтік мәндер шегінде силикатты модулі бар сұйық әйнектің шығуы бойынша ең жақсы нәтижеге қол жеткізілетіні анықталды. Осылайша, Тасқала кен орнының опокасын сұйық шыны өндіру үшін шикізат ретінде пайдалануға болады, зертханалық сынақтармен және процестің техникалық-экономикалық негіздемесімен расталады.

**Түйін сөздер:** сұйық шыны, опока, кремний шикізаты, Тасқала кен орны, кремний диоксиді, силикатты модуль, натрий гидроксиді, калий гидроксиді, химиялық өңдеу.

**Introduction.** Liquid glass is widely used in various industries due to its unique properties, including: mechanical engineering (as a binder for making molds and cores); pulp and paper industry (for impregnating paper pulp and as an adhesive for containerboard and corrugated boxes); chemical and petrochemical industry (for the production of catalysts, white soot, zeolites, silica sol, silica gel, synthetic detergents, and oil cracking, etc.); construction materials industry (for the production of concrete structures and products, for the reinforcement of soils in the construction of roads, airfield coatings, foundations, etc.); paint and varnish industry (as a film-forming agent in the composition of silicate paints and anti-corrosion primers).

Traditionally, quartz sand is used for its production, but alternative sources of silica, such as opoka, are of interest from a resource-saving perspective. One of the main criteria for determining the suitability of this raw material is its maximum content of amorphous $SiO_2$ and its minimum content of impurities, which can contaminate alkaline silicate solutions and lead to the formation of insoluble residues [1-4].

The opoka of the Taskalinsky deposit is characterized by a high content of amorphous silica, which makes it a promising raw material for the production of liquid glass.

The aim of this work is to obtain liquid glass from the opoka of the Taskalinsky deposit in the West Kazakhstan region and to determine the optimal conditions for its production, as well as to analyze the compliance of the resulting product with the requirements of GOST 13078-81.

The object of the study is the siliceous rock, the opoka of the Taskalinsky deposit in the West Kazakhstan region.

**Materials and methods.** At the initial stage of the work, comprehensive studies were conducted to assess the physical and mechanical properties and chemical and mineralogical composition of the selected raw material. The results obtained are presented below. The

X-ray phase analysis was performed using a Clever C-31 X-ray fluorescence spectrometer, and the elemental composition was determined using a CHNS-O ECS 80 elemental analyzer using the Dumas method.

Figure 1 shows an X-ray diffraction pattern of a siliceous rock (opoka) sample obtained by X-ray phase analysis. The measurements were performed in the 2θ range from 3° to 30° using an X-ray diffractometer at a voltage of 45 kV and a current of 30 mA, using CuKα radiation (λ = 1.5406 Å).

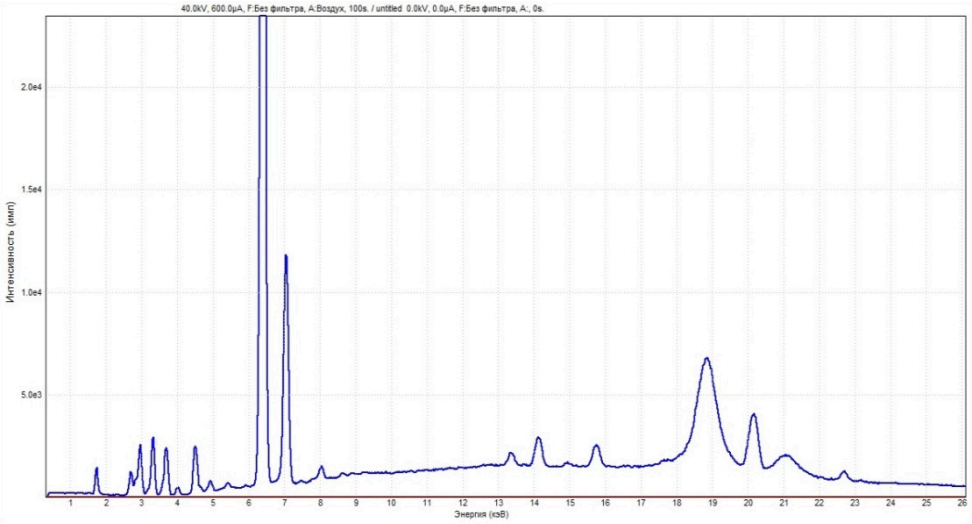



**Fig. 1 – X-ray diffraction pattern**

Diffraction pattern shows intense diffraction peaks in the 2θ range of 5-9°, which corresponds to the presence of amorphous and weakly crystalline silica, primarily in the form of opal. Additionally, there are less intense peaks in the 2θ range of 19-23°, which are characteristic of impurities such as quartz, clay minerals, and possibly glauconite. The broad and faint peaks indicate the presence of an amorphous phase, which is typical for siltstones rich in amorphous silica. The opoka of the Taskalinsky deposit was analyzed for its chemical composition (Table).

**Table 1 - Chemical composition of the Taskalinsky opoka deposit**

| Oxide content, wt % | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | $Al_2O_3$ | $TiO_2$ | CaO | MgO | $Fe_2O_3$ | $SO_3$ | $Na_2O$ | $K_2O$ |
| 66,98-83,5 | 5,76-12,95 | 0,1-0,62 | 0,24-17,9 | 0,43-1,39 | 1,39-4,80 | 0,03-0,97 | 0,15-0,78 | 1,13-2,85 |



**Fig. 2 – Photo of the Taskalinsky deposit's opoka**

According to the chemical analysis data (Table 1), the sample meets the requirements for the following indicators: silicon dioxide content is not less than 80%, aluminum oxide is not more than 7%, and the iron oxide content is within the permissible concentration limits.

Mineralogical composition of the Taskalinsky deposit of the West Kazakhstan region is represented by opal 54-78%, clay minerals 15-22%, calcite up to 6%, quartz 4-7%, mica 2-4%, glauconite 2-3%, and organogenic residues up to 12%.

Textural and structural properties were studied for the rock. The texture is layered. The structure is fine-grained and pelitomorphic. The color is light yellow, and the layers are orange. The red-orange layers are composed of iron-containing compounds.

**Results and discussion.** The opoka was studied using synchronous thermal analysis (TG). Study was conducted using a synchronous thermal analyzer STA 6000. The shooting modes were as follows: temperature range of 30-830°C, heating rate of 10°C/min, and the medium was air. The thermal curve with the maximum peaks (TG) is shown in Figure 3. In the temperature range of 25-1500C, an endothermic effect with a mass loss of 9.19% is observed due to the release of hygroscopic water. Further, in the range of 150-350°C, a mass loss of 0.64% is observed. This effect indicates the gradual oxidation and combustion of the organic component of the sample. The total mass change in the range of 30-830°C is 11.83% mass.

Calcination temperature for the opoka was chosen to be 3500C based on the thermogram (Figure 3).

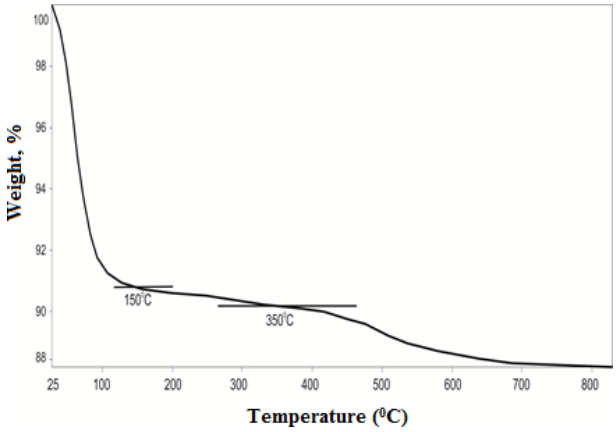



**Fig. 3 – Thermogram of the opoka**

Results of the mineralogical composition of the opoka indicate its siliceous nature with a predominance of opal. The presence of clay minerals, organogenic residues, and minor impurities (calcite, quartz, glauconite, and mica) indicates its sedimentary origin and confirms its suitability for producing composite materials.

As part of the study, electrostatic separation was used to enrich natural siliceous raw materials, such as the Taskalinsky deposit of opoka. The material fraction with a particle size of 0.63 mm was separated using the ELKOR-1 electrostatic drum separator manufactured by Mehanobr-Technika JSC.

Electrostatic separation is based on the different ability of minerals to become electrically charged under the influence of an external electric field. The method allows for the effective separation of mixtures based on their electrophysical properties. Conductive and weakly conductive components (such as clay minerals, organic matter, and weakly oxidized impurities) are deflected in one direction, while dielectric materials like opal and quartz exhibit a different trajectory and are collected in a separate fraction.

Obtained data indicate the predominantly siliceous composition of the studied material and confirm its suitability as a raw material for producing liquid glass.

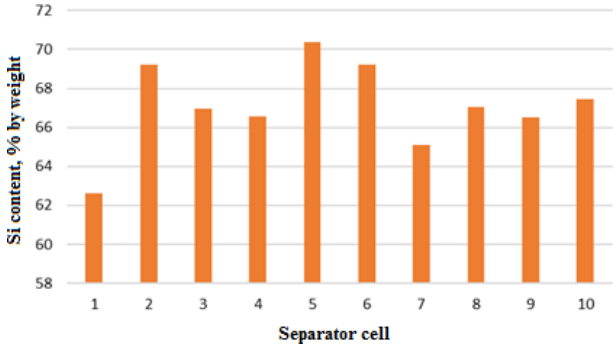



**Fig. 4 – Results of electrostatic separation**

Results (Figure 4) show that the silicon content in all separator cells is more than 50%, which makes it impossible to separate the impurity compounds from the silicon oxide.

Key physical and chemical characteristics of mineral raw materials that determine their quality and technological suitability are: specific surface area (at least $115 \cdot 10^3$ m²/kg), nitrogen porosity (at least $0.200 \cdot 10^{-3}$ m³/kg), and average pore diameter (in the range of 7-10.5 nm), among other parameters.

Results of the analysis of the structural characteristics of the studied opoka indicate that, according to the classification of siliceous rocks, the opoka of the Taskalinsky deposit belongs to the category of relatively mesoporous materials. This is confirmed by the effective pore diameter value of over 8 nm and the specific surface area exceeding $118 \cdot 10^3$ m²/kg. Additionally, the benzene pore volume ($0.251 \cdot 10^{-3}$ m³/kg) meets the established technical requirements for this type of raw material.

As can be seen from the results of the component, chemical composition, and adsorption-structural properties of the Taskalinsky deposit opoka, the latter meets all the requirements for glass raw materials.

To obtain liquid glass in laboratory conditions, the Taskalinsky deposit opoka was used as a silicon-containing raw material. The raw material was first crushed to a fraction of 0.1-0.7 mm and then calcined at a temperature of 350 °C for 2 hours to remove moisture and organic impurities.

Based on the conducted patent research [5-10] and the analysis of published materials [11-16], the authors developed an approach to technological research of opoka.

Experiment on the synthesis of liquid glass was carried out using the alkaline decomposition method of the Taskalinsky deposit. A 20% aqueous solution of NaOH was used as a reagent, taken in a 1:1 mass ratio to the raw material. The reaction mixture was heated at 90°C for 2-3 hours with constant stirring. After the dissolution process was completed, the product was cooled and filtered to separate the insoluble residue. The resulting silicate solution was concentrated to a density of 1.31.4 g/cm³ if necessary. The final product was characterized by its silicon dioxide content, pH, density, and silicate module ($SiO_2/Na_2O$).

Resulting product is a homogeneous transparent solution with a silicate module of 3.1, suitable for use in construction, foundry production, and other industries.

Chemical analysis showed that the ospock contains 75% amorphous silica, which meets the requirements for the production of liquid glass. Pre-treatment with heat increased the yield of the product. Optimal processing parameters resulted in a liquid glass with a module of 3.1, which meets the requirements of GOST 13078-81.

**Conclusion.** The opoka of the Taskalinsky deposit in the West Kazakhstan region is a promising natural raw material for the production of liquid glass due to its high content of amorphous silicon dioxide, porosity, adsorption capacity, and availability in the region. The conducted studies of the chemical and mineralogical composition have shown that this material meets the requirements for siliceous raw materials used in the production of silicate compositions.

The proposed processing technology includes alkaline treatment of opoka with a 20% solution of sodium hydroxide at a temperature of 95-98 °C for 2-3 hours in a ratio of raw material to alkali of 1:2. As a result, a high yield of a product with the required physical and chemical properties is achieved. The resulting liquid glass meets the requirements of GOST 13078-81 in terms of $SiO_2$, $Na_2O$ content, and silicate module of 3.1.

Thus, the implementation of this technology allows for the efficient use of local natural resources for the production of liquid glass, reducing dependence on imported raw materials and increasing the economic profitability of production. Additionally, it contributes to the development of the regional mineral resource base and can be beneficial for enterprises in the construction, chemical, and glass industries.

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