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Justification of an acceptable modern energy-efficient method of obtaining sodium silicate for production in Kazakhstan

K K Yelemessov, D D Baskanbayeva, L B Sabirova and
Sh D Akhmetova

Satbayev University, 22a Satpaev Str., Almaty, 050043, The Republic of Kazakhstan

E-mail: k.yelemessov@satbayev.university, d.baskanbayeva@satbayev.university,
slb2609@mail.ru, sh.akhmetova@satbayev.university

Abstract. Sodium silicate is used in various industries. Sodium silicate is a basic component in the production of silicate adhesives and paints, silica gel, welding electrodes, corrugated packaging, and geopolymer concretes and cements. All this is currently not produced in the Republic of Kazakhstan. The article discusses the methods of production of sodium silicate and substantiates the possibility of organizing production in the Republic of Kazakhstan. The authors have studied all the available experience in the production of sodium silicate, both now and in the past. At this stage of the research, an analysis was made of the experience in the production of serial and pilot sodium silicate in the USSR in the past and in countries where development has not been suspended at the present time. All possible sources of raw materials of technogenic and natural origin were studied. Business trips and expeditions to natural deposits were carried out and samples of raw materials from various natural and man-made sources were delivered. Studies have been carried out to determine the available volumes of raw materials. Various technologies for melting sodium silicate have been studied, incl. by unconventional schemes, such as smelting in cyclone furnaces. For melting in electric furnaces, various schemes of energy-saving methods for melting sodium silicate were analyzed. Promising ones have been identified. The following types of sodium silicate production were analyzed in the study: traditional smelting (carbonate method), wet method, sodium chloride sublimation method, sulfate method, cullet smelting. The optimal variant has been chosen, which makes it possible to reduce the cost of electricity by several times when introducing a highly efficient innovative technology of electric melting into practice.

1. Introduction

Sodium silicate has found wide application in many industries. It is used as a component of the charge for the production of glass, a filler in the composition of lightweight cement mortars for cementing wells, in the production of heat-resistant and acid-resistant concrete. As for the chemical industry, sodium metasilicate is used in the production of detergents and cleaning agents, household chemicals (Henkel washing powder). It is also widely used in oil production (as a coagulant in the production of regenerating oil) and the textile industry, metallurgy, mechanical engineering. Sodium silicate is used as an inhibitor with a corrosive effect, for disinfection of premises, linen, dishes, plumbing. Interestingly, silicates are one of the components of precious stones (emerald, topaz, aquamarine). They are used as a fire-fighting impregnation for wood



(decoration processing), a mixture of sawdust and silicate fills the gap between the walls of safes also to protect against fire [1–3].

Sodium silicate is a basic component in the production of silicate adhesives and paints, silica gel, welding electrodes, corrugated containers, and geopolymer concretes and cements [4,5]. All this is currently not produced in the Republic of Kazakhstan. As for its use in the production of building materials, the technology is needed by all existing enterprises in the production of small-piece building materials, as well as all enterprises producing reinforced concrete products in regions where there are blast furnace or thermophosphoric slags [6–8].

The technology of production of foam concrete based on geopolymers using sodium silicate is of the greatest interest, since here the strength of foam concrete depends on the strength of the elementary bubble, which, as is known, can be 2-3 or even 4 times stronger than in the case of traditional foam concrete based on Portland cement [9].

It follows from the above that sodium silicate is a widely applicable and necessary component for some industries. Thus, liquid glasses are used as a component of cements – heterogeneous systems, as well as an inorganic adhesive. As a “bundle” or “cured bundle”, water-soluble silicates are used both for the manufacture of composite materials and coatings, and for gluing parts and assemblies of aggregates for various purposes.

In this regard, the authors have studied all available experience in the production of sodium silicate, both now and in the past. At this stage of research, the analysis of the experience of the production of sodium silicate, both serial and pilot-industrial in the USSR in the past and in countries with not suspended development at the present time, was carried out.

Various technologies are classified.

Further, all possible sources of raw materials of both man-made and natural origin were studied. Business trips and expeditions to natural deposits were carried out and samples of raw materials from various natural and man-made sources were delivered. Studies have been conducted to determine the available volumes of raw materials.

Various technologies for melting sodium silicate have been studied, including using unconventional schemes, such as melting in cyclone furnaces. For melting in electric furnaces, various schemes of energy-saving methods for melting sodium silicate were analyzed. Promising ones have been identified.

Polymer concretes made with the use of slag-alkali binders showed increased quality characteristics, such as: strength, frost resistance, heat resistance, durability and impermeability. However, there is a shortage of inexpensive alkaline components on the market of the Republic of Kazakhstan, which would speed up cation exchange processes in the astringent system and increase hydration activity.

In Kazakhstan, there are unlimited natural reserves of sodium sulfate, when melting with lime, soda melt (a mixture of soda and gypsum) is obtained, which is a necessary component of slag-alkaline binders.

Soluble sodium silicate (soluble glass or silicate block) is the most multi-tonnage product of inorganic chemistry and is used in many industries:

- 1) Geopolymers;
- 2) Corrugated cardboard, books and other printing products;
- 3) Welding electrodes (coating);
- 4) Refractory and acid-resistant concrete;
- 5) Foam glass;
- 6) Cement Chipboard;
- 7) Foam concrete;
- 8) When arranging waterproofing during construction work;

- 9) Silica gel (adsorbent);
- 10) In metallurgy for molding injection mixtures;
- 11) In mechanical engineering for bundles for briquetting metal chips;
- 12) Flotation reagents in the enrichment of non-ferrous metals, primarily zinc;
- 13) Soap and washing powder;
- 14) In the rubber industry as a raw material for white soot (rubber filler);
- 15) In the food industry as an emulsifier E550.

The authors are working in the field of reducing energy costs. For this purpose, the technology of reactive power compensation with a magnetic amplifier is proposed, which is key, can be used in hundreds and thousands of companies only in Kazakhstan, where there are significant unit costs for electricity – from mining to street lighting.

2. Materials and methods

Sodium silicate is the most multi-tonnage product of inorganic chemistry. The greatest interest in obtaining sodium silicate with a low cost is shown by manufacturers of geopolymer cements, which require it to produce clinker-free binders. In the production of conventional cement, up to 400 kg of coal is burned for each ton of clinker. At the same time, almost one and a half tons of carbon dioxide are emitted into the atmosphere. In the production of clinker-free cement, granular blast furnace slag is used, of which more than 50 million tons have been accumulated in Temirtau, and the clinker firing process is excluded. However, sodium silicate (aka silicate-block) is also required, when added in an amount of 6-10%, cement of the M800-M1000 brand is obtained! In addition to the construction materials industry, the silicate block is used in a variety of industries (construction, printing, production of corrugated packaging, in the production of adsorbents). Currently, it is not produced in the Republic of Kazakhstan. Usually, a silicate block is obtained by melting quartz sand with soda in bath-type gas furnaces. Such furnaces have a characteristic size of about 40 m and are very expensive due to the use of a large number of refractory materials [10].

The authors are conducting research in the field of possibilities to use an electric direct heating furnace, which provides the same result with dimensions, and, accordingly, the cost is an order of magnitude lower. Considered below are past and present experiences in the production of sodium silicate.

Traditional melting (carbonate method). Currently, most glass industry enterprises in the CIS countries use soda ash and/or mixed with sodium sulfate for melting silicate blocks (figure 1).

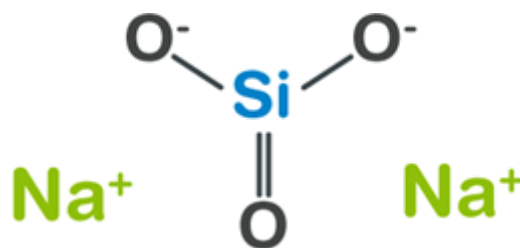
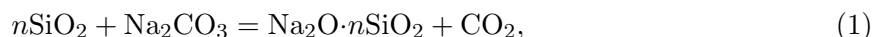


Figure 1. Structure of sodium silicate.

In a mixture with quartz sand, sodium carbonate (soda ash) or potassium carbonate are melted in flared glass furnaces of continuous operation. The reaction proceeds according to the following reaction:





This technology, firstly, requires significant capital expenditures for the construction of glass furnaces, so this method is unacceptable for our task. Secondly, the cost of soda ash at the level of 100 thousand tenge per ton with delivery to Karaganda also makes it impossible to fit into the specified cost range, since the amount of soda in the charge is 40%, i.e. the cost of soda alone will amount to 40 thousand tenge per 1 ton of sodium silicate [11].

We took a trip to Lake Tanatar (Altai Krai, Russia) to study the market in order to reduce the cost of soda ash. There is an enterprise for the extraction of natural soda. As will be further shown in paragraph 2 of this study, the use of natural soda from the Altai Krai is impractical.

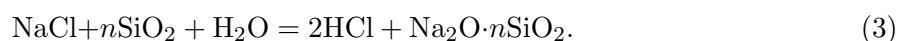
Wet method. In China, where there are large enterprises for the production of soda ash, a wet method for producing liquid glass by dissolving finely ground quartz sand in a saturated solution of caustic soda is widespread [12].

The large source of amorphous silica available in Karaganda (waste from the production of the “Silicium Kazakhstan” plant) makes this production method very attractive, since the dissolution of amorphous silica occurs much faster and with lower energy costs than quartz sand. The reserves available at the landfill of the enterprise amounted to about 50 thousand tons in 2019. The cost was 3,000 tenge per ton. Part of the amorphous silica was purchased by us and studied at our request by Vladimir Merkulov, professor of the Karaganda State Industrial University for solubility in a 40% caustic soda solution in the laboratory of the Karaganda Industrial Institute. The result of the dissolution reaction was a liquid glass of black color, which is applicable for the production of slag-alkali cement.

However, the cost of caustic soda in the Republic of Kazakhstan at the level of 300 thousand tenge per 1 ton turned out to be unsuitable for any wet method technology due to the high cost.

The method of sublimation of sodium chloride. Of great practical interest are the works carried out in the USSR in the 50 s of the 20 th century on the production of sodium silicate by sublimation of sodium chloride in the presence of water vapor through quartz raw materials [13].

In this case, at temperatures of 600-1000 degrees Celsius, table salt and sodium ions react with quartz glass to produce sodium silicate:



This method is very attractive for practical implementation due to the low cost [14].

Due to the presence of a high content of unreacted silicon oxide, liquid glass, which is obtained by further dissolution of sodium silicate, contains a large amount of insoluble residue unacceptable by any standards, which, in principle, could be eliminated by conventional filtration, but, apparently, this method has not found practical application for reasons of production safety [15].

The group of liquid glasses – alkaline silicate solutions is very extensive. The silicate systems included in this group are classified according to the following criteria.

According to the degree of polymerization (l) of silica – the average number of silicon atoms that form a continuous system of siloxane bonds $\equiv \text{Si} - \text{O} - \text{Si} \equiv$ during polymerization. During the polymerization of silica, its molecular weight (M) increases, and at high degrees of polymerization, an increase in the size (d) of colloidal silica particles occurs. At a certain degree of polymerization (l), colloidal silica appears in alkaline silicate systems both in the form of a sol and in the form of highly dispersed hydrated silica (table 1).

According to the chemical composition, as the alkalinity increases, characterized by the molar ratio $\text{SiO}_2/\text{M}_2\text{O}$ (the silicate module of the n system), alkaline silicate systems form a series corresponding to the four above forms of silica (table 2).

By monitoring the cation of liquid glasses, potassium, sodium, lithium and silicates of industrial enterprises are monitored. Mixed liquid glasses within four groups have also been synthesized.

Table 1. Degrees of polymerization of silica silicate solutions.

Monomers ($l = 1$)	→	Lower oligomers ($l = 1 \div 25$)	→	Higher oligomers (polysilicic acids, $M < 10^5$)	→	Colloidal silica, sols ($M > 10^5$ or, $d > 2nm$)
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Table 2. Rows with increasing alkalinity of silicate solutions.

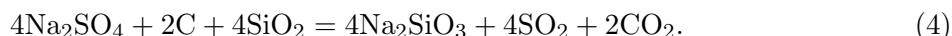
High alkaline systems ($n < 2$)	→	Liquid glasses ($n = 2 \div 4$)	→	Polysilicates ($n = 4 \div 25$)	→	Sols ($n > 2$)
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The biggest disadvantage of this method is that, firstly, very toxic hydrochloric acid vapors with high temperature require expensive hardware for their cooling and dissolution in water, and secondly, the production of hydrochloric acid requires licensing [13].

Sulfate method. There are quite large deposits of sodium sulfate in Kazakhstan, which are currently not in demand by anyone.

The sulfate method for producing soluble glass is based on the interaction at high temperatures (1300-1500°C) of sodium sulfate with silica in the presence of a reducing agent (most often charcoal) [14].

In general, the process of formation of sodium silicate can be expressed by the equation:



The reaction between Na_2SO_4 and silica, even with a significant increase in temperature, proceeds slowly and quantitative completion of it is almost impossible.

In order to accelerate the reaction, it is necessary to add a reducing agent to the charge to convert Na_2SO_4 to Na_2SO_3 , which reacts with silica.

The reducing agent can be various organic substances containing carbon: sawdust, charcoal, resins, coal pitch, etc. Sawdust and charcoal are low-ash. This allows them to be widely used in the production of soluble glass.

The reducing agent, burning inside the melt, attaches oxygen contained in Na_2SO_4 , as a result of which the latter passes into sodium sulfite Na_2SO_3 .

Coal is added to the charge in an amount of 3-7% by weight. The amount of reducing agent introduced into the charge significantly affects the properties of the resulting soluble silicate.

With an insufficient amount of reducing agent, Na_2SO_4 remains in the melt, which does not mix with sodium disilicate and silica, which is in excess against the formula Na_2SiO_3 and $\text{Na}_2\text{Si}_2\text{O}_5$, and causes the alloy to delaminate.

With an excess of carbon in the melt, sodium sulfide Na_2S is obtained, which forms iron sulfide FeS when interacting with iron oxides, staining the soluble glass in dark colors [16].

Since, for cost reasons, this method, subject to obtaining a license for subsurface use, turns out to be the most attractive, we have studied this method more closely with the involvement of OOO "Research Institute Stromcomposite" Krasnoyarsk, Russia.

The sulfate method proposed by Krasnoyarsk NIISTromproekt, as well as the method of salt distillation described above, allows to obtain a silicate block with a low cost due to the use of a number of heat-saving aggregates [17].

Thus, it is the sulfate method with the condition of using energy-saving solutions that could become the way that would ensure the cost of the silicate block at a given level, but it has a number of significant drawbacks:

- Formation of sulfur dioxide, which requires neutralization and, accordingly, additional capital costs [11];

- As well as in the carbonate method, this one provides for the construction of an expensive glass furnace; which, in the absence of natural gas (Karaganda), also requires additional capital costs for the production of generator gas from coal.

Melting of cullet. The difference between construction or bottle glass and silicate blocks is only that the amount of soda in the raw charge in the latter case is 15% more [18].

Currently, cullet in the Republic of Kazakhstan is formed not only in window shops, but also in numerous service stations for the replacement of automobile windows. The currently unclaimed secondary glass container market is added to this volume.

In Karaganda, the service for collecting glass from window shops with delivery to the intended place of consumption is 3,000 tenge per ton. Here it is required to add 15% soda ash or sodium sulfate, i.e. the cost of raw materials in this case will be no more than 18,000 tenge per 1 ton. Processing processes (crushing and sorting), wage costs and other overhead costs will amount to about 3,000 tenge per ton. Thus, excluding energy costs, the total cost will be 21,000 tenge per 1 ton of silicate blocks. Such preliminary calculations make the processing of cullet along with sodium sulfate one of the likely ways to solve the engineering and economic task.

Study of potential sources of raw materials. Sodium silicate, produced in the form of a silicate block by Russian enterprises, is currently imported to the Republic of Kazakhstan, where it is dissolved in water and further used at enterprises of the construction, corrugated cardboard and, mainly, metallurgical industry. The most tonnage direction for the sale of sodium silicate could be the sector of production of polymer cements and concretes. The main problem in the production of annealed, clinker-free binders obtained from the waste of steelmaking enterprises (granulated blast furnace slag) is the lack of inexpensive primary or secondary alkaline materials on the market that can not only activate such binders, but also match the low price of traditional Portland cement [19].

Melting a sodium silicate block requires silicon dioxide and a suitable source of sodium.

Silicate raw materials can be man-made sources, such as cullet and microsilicon, as well as natural quartz sand [20].

Natural inexpensive sources of raw materials can be natural soda and sodium sulfate. Unfortunately, there are no technogenic alkaline sources in Kazakhstan in practically applicable volumes.

The experience of the silicate-block workshop in the Soviet period, which worked in Balkhash on the territory of the copper smelter, showed that the use of sodosulfate waste from the Pavlodar aluminum plant allowed to obtain high-quality silicate-block with a very low cost. However, along the way, an unacceptably high level of sulfur dioxide emissions was formed, which seemed insignificant “under the cover” of the main production of the combine, which also emits a huge amount of sulfur dioxide. The sodosulfate mixture is an excellent and cheap raw material for melting silicate blocks (if the furnaces are equipped with equipment for neutralizing sulfur dioxide), but the Pavlodar aluminum plant has changed the technology and does not currently ship the sodosulfate mixture.

Another inexpensive source, besides the soda-sulfate mixture, could be a deposit of natural soda. As it is known in the USA, it is due to the use of natural garden raw materials that the bulk of silicate blocks is produced.

Natural, and therefore inexpensive, soda raw materials in Kazakhstan in the explored deposits are available in negligible quantities. For example, a deposit with reserves of less than 500 tons is known in the Almaty region.

In the Altai Krai, water from Lake Tanatar with a soda content of about 5% is pumped into sedimentary basins, in which, when the temperature drops, soda precipitates, and the water drains back into the lake. There is no soda drying at the enterprise. Therefore, in addition to the natural humidity of 17%, each soda molecule contains 10 more molecules of chemically bound water.

Moreover, production was suspended after a single buyer from Stepnogorsk stopped acquiring it, after which the Altai Soda company went bankrupt. Currently, it is not possible to purchase soda from this source. It should be noted that even before the bankruptcy, the price at the level of 60 USD per 1 ton at the Kulunda station was unacceptable due to the high-water content (both chemically bound and free moisture). It turned out that 60-70% of water had to be transported, not soda. Thus, this source of raw materials for use in the production of slag-alkali cement was also unacceptable.

As a result, we came to the conclusion that cullet is currently the most suitable as the main source of raw materials, which is not only a source of silicate, but also sodium raw materials.

During the study, we found that the waste landfill of the city of Karaganda is ready to supply 200 tons of cullet every month. And together with the city of Astana and other cities of Central Kazakhstan, the total volume of available cullet is estimated at around 1000 tons per month. Other sources are workshops for the production of windows and replacement of car windows. The films inside the triplex are a harmful impurity, they are coked during melting, giving a dark color, but for a silicate block that will be used in the production of slag-alkaline cement, this is permissible.

3. Results and discussion

The main elements of modern furnaces that allow saving energy are various heat exchangers that usefully use secondary heat. In glass furnaces, fuel gases can be used to warm up incoming raw materials.

In the technological scheme proposed by OOO "Research Institute Stromcomposite" Krasnoyarsk, Russia, fuel gases are also used to produce charcoal used in the sulfate method: Sodium sulfate Na_2SO_4 (0.91 t/h), burnt molding earth (1.46 t/h) and charcoal (0.56 t/h) are fed into the melting furnace.

The components are pre-crushed and homogenized in a rod mixer.

Melting is carried out due to the combustion products of the generator gas coming from the gas generator, in which the working medium is charcoal. With an average coal consumption of 0.42 t/h in the gas generator, 2800 kg/h (2240 nm^3/h) of gengas is formed. The combustion of this amount of gengas with the supply of 2700 kg/h (2100 nm^3/h) of blast air into the combustion chamber produces 5500 kg/h of combustion products with a temperature of approximately 1550°C and a heat content of 2.9 Gcal/h.

At the outlet of the melting furnace, the temperature of the combustion products decreases to 9000°C with a residual heat content of about 1.5 Gcal/h. The total mass of the combustion products reaches approximately 6100 kg/h due to the addition of the products of the silicate block formation reaction: CO and SO_2 . The amount of the first is approximately 0.18 t/h, the second is 0.42 t/h.

The combustion products are subjected to oxidative afterburning, for which 600 kg/h (465 nm^3/h) air is supplied to the afterburning chamber. As a result of afterburning, the amount of combustion products increases to 6700 kg/h, its heat content increases to 1.9 Gcal/h, and the temperature increases to 1000°C.

These combustion products are sent to retorts for dry distillation of wood waste. The retort capacity is 1 t/h of charcoal. If the initial moisture content of wood waste is 40%, then the required amount of wood waste is 5.5 t/h.

As a result of dry distillation, the heat content of combustion products drawn through the wood layer increases due to exothermic reactions of wood decay by 0.8 Gcal, however, approximately 0.3 Gcal/h is lost to the environment, and, with the charcoal leaving the retort [21].

Thus, the total heat content of combustion products at the outlet of the retort reaches 2.4 Gcal/h, and their mass increases to 11200 kg/h due to the addition of 4.5 t/h of volatile decay

products. The temperature of the combustion products at the outlet of the retort will be approximately 650°C.

Volatile wood decay products contain: CO, acids, alcohols, ketones, light hydrocarbons, resin vapors, free hydrogen, therefore they must be subjected to afterburning. In 4.5 t/h of volatile, combustible compounds 1200 kg, the rest is physical and pyrogenetic water, CO₂, N. With an average calorific value of a mixture of combustible compounds 4500 kcal/kg, afterburning of volatile compounds taking into account losses allows you to get an additional 5.4 Gcal/h. For afterburning, blowing air is used in an amount of 2500 kg/h.

Thus, 13700 kg/h of combustion products with a heat content of 7.8 Gcal/h come out of the afterburning chamber.

The combustion products are sent to the heat recovery boiler G 400-PE-1 for the production of 10 t/h of steam with parameters: $T_p = 260^\circ\text{C}$, $R_p = 14$ atm.

Of the 10 t/h of steam, 3.7 t/h is spent on the production of electrical energy in the block electric turbine generators TGV-500M, the remainder is used for technological needs.

The process of hardening of liquid glass is accompanied by the manifestation of adhesion properties to the quartz sand filler and is carried out with natural (in air) or artificial (heating, blowing warm air) drying of the mixture. In contrast to the manufacture of casting molds, in this process it is necessary to avoid the destruction of the liquid glass base in order not to further reduce its solubility in water.

In addition, to achieve high strength, first of all, it is necessary to achieve the most dense packing of sand grains, which, in addition to molding pressure, requires a certain grain size distribution and optimal viscosity of liquid glass. In this case, the dependence of strength on the glass content in the system passes through a sharp maximum. This dependence is shown in figure 2.

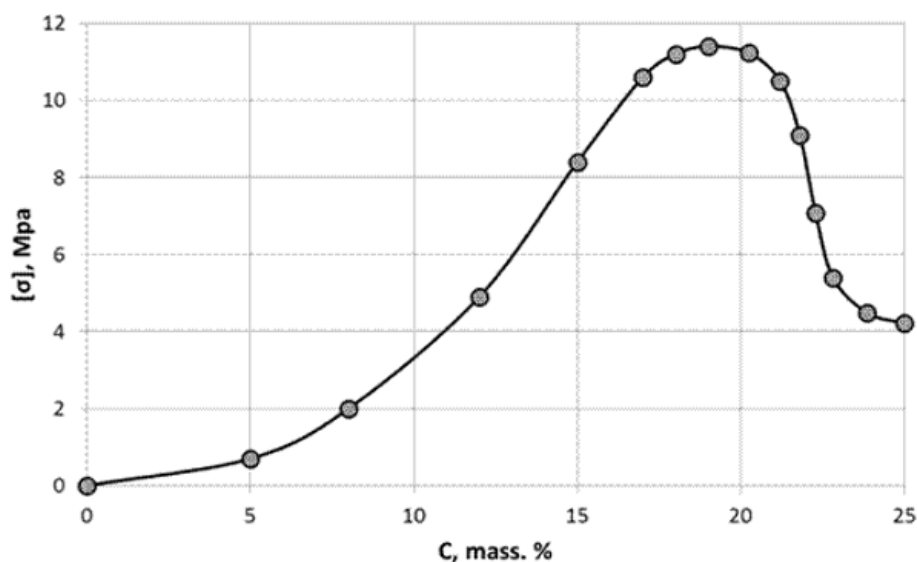


Figure 2. Dependence of the tensile strength on the content of liquid glass.

After the recovery boiler, the combustion products are neutralized in a “wet” scrubber [22].

The high cost of glass-melting furnaces of the bath type, which are used in glass factories with a capacity of 40-60 tons per day, is estimated at 2-3 million US dollars. This goes beyond the boundary conditions. Sodium silicate is a key source of reactive silica, which is in high demand in many industries including detergents, rubber, food and beverages, and paper and pulp. The

global sodium silicate market was valued at USD 6.3 billion in 2018, growing at a CAGR of 3.2% during the forecast period 2020-2026 figure 3.

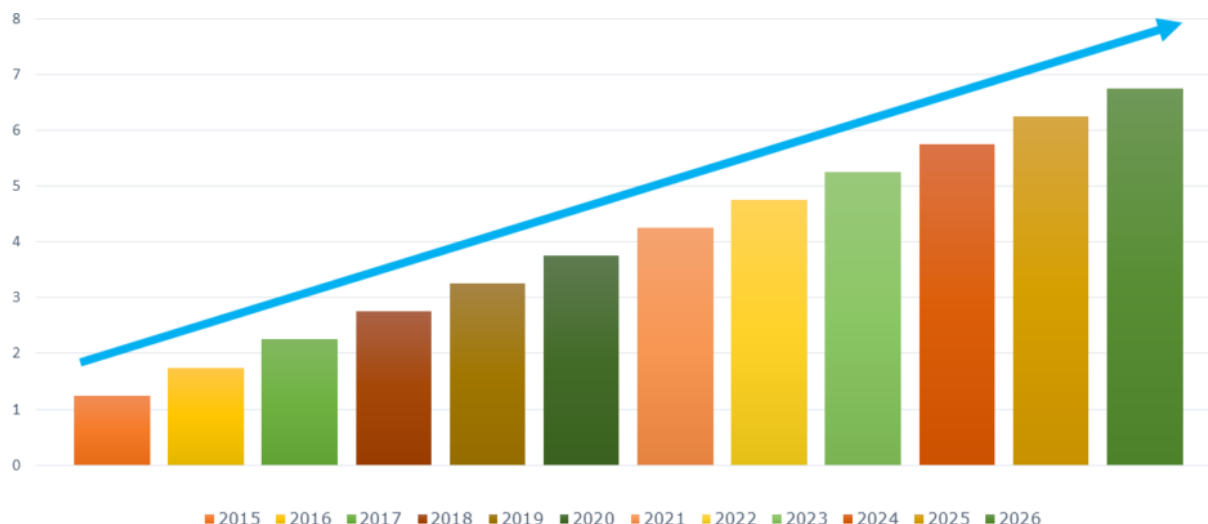


Figure 3. Global market forecast according to [23].

The growing demand for other derivatives such as silica gels and silica sols in applications including paints and coatings, plastics and inks is expected to have a positive impact on market growth during the forecast period. Another promising melting method would be glass melting in a cyclone furnace [18].

Scientists of the Academy of Sciences of the Kazakh SSR were seriously engaged in this topic in the 70s of the 20th centuries and were among the world leaders. Such an experimental furnace was even used for melting copper raw materials at the Balkhash copper Smelting plant.

Cyclone furnaces consume 1.5-1.6 times less fuel than rotary furnaces, and have a cost 10-20 times less in terms of capital costs for their construction [10].

It turned out that cyclone furnaces are currently used to produce mineral and glass wool in Germany.

The main disadvantage of melting raw materials in a cyclone is the huge volume of fuel gases that require purification. The fact is that in cyclone furnaces, the charge in a pulverized state with speeds of several hundred km/h is blown into the cyclone together with fuel gases. Some of the raw materials are melted, but some come out of the cyclone, which leads to a loss of raw materials up to 15%. At the same time, there is a technical problem of cooling the flow of the outgoing gas and its purification from solid impurities. Such a task is quite feasible, but in the given parameters of the task it will require the construction of a battery of heat-resistant cyclones, the cost of which is higher than the cost of the furnace itself.

Therefore, our research should be in the field of energy saving of electric direct-heated glass furnaces. The design of such furnaces is simple, requires little space and capital costs. The only drawback of such furnaces is the high-power consumption – 1000 kw-hours of electricity is required for 1 ton of silicate blocks, which at current prices is 16,000 tenge per ton of silicate blocks.

As part of the task, it is required to reduce the electricity consumption to 7000-8000 tenge per ton of silicate blocks. In the course of the conducted scientific and technical search, it turned out that currently there are technologies that can reduce consumption costs by 2 or even more times.

The main component is an electric direct heating furnace. The efficiency of such furnaces is

many times higher than the efficiency of gas furnaces, since in our case the heat flow is carried out from below (bottom electrodes), and not from above, as in the case of coal or gas furnaces, where the torch heats the mass from above, which is why it is necessary to build an expensive vault. But in our case, the electric furnace is additionally equipped with a reactive energy compensation unit with a magnetic amplifier, as a result of which electricity is saved at least 2 times.

The authors are engaged in the introduction into practice of a highly efficient resource-saving process for the production of sodium silicate from cullet with the use of innovative electric melting technology, which allows a multiple reduction in energy costs and the use of energy-saving technology for obtaining an aqueous solution of sodium silicate using a highly efficient apparatus protected by a patent.

The introduction of the proposed technology will allow not only to start a solution for import substitution, but also to indicate a technical solution for involving tens of millions of tons of Temirtau and Taraz slag into economic turnover, which will reduce carbon dioxide emissions by reducing the production of Portland cement, which currently produces carbon dioxide in rotating coal furnaces almost more than cement itself.

In addition, it is planned to obtain sodium silicate not from quartz raw materials and soda, but from secondary glass and soda, since there is already a high amount of sodium oxide required in the cullet. Another difference of the proposed technology is the use for electric melting of a furnace equipped with a reactive power compensation unit with a magnetic amplifier, which will make it possible to reduce the specific amount of electricity by at least 2 times.

The second technical difference is the technology of dissolution of sodium silicate. Traditionally, sodium silicate is dissolved in water in autoclaves at high vapor pressure, which is too energy-consuming. In our case, the silicate block is crushed and dissolved in water at a temperature of 95-98 degrees Celsius at normal pressure. At the same time, an energy-efficient device is used, protected by patent No.2397 with the authorship of one of the team members – T. S. Dauletbaev [24].

The traditional technology of melting sodium silicate involves melting quartz sand and soda in bathroom furnaces. This technology, firstly, requires high capital investments for the construction of a bathroom furnace, and secondly, requires the presence of a source of natural gas or where there is none, as in our case, a gas generator set for the production of generator gas from coal, which also increases the cost of the project [11].

The technology of dissolving quartz sand in caustic soda solution is also known, which sharply increases the cost of products due to the high cost of NaOH (caustic soda). The technology of obtaining sodium silicate from cullet with the addition of 8-15% soda ash (Na_2CO_3) is also used with melting in bathroom furnaces and is the closest to this project.

We propose the production of sodium silicate from cullet with soda and / or sodium sulfate, but, characterized in that:

- Melting is carried out not in an expensive bath-type gas furnace, but in a compact electric furnace of direct heating;
- The electric furnace is equipped with a reactive power compensation unit with a magnetic amplifier, which gives a multiple reduction in electricity consumption of at least 2 times;
- The components of the charge are mechanically activated in a roller mill before melting.

This leads to a partial reaction of the formation of sodium silicate already in the mill and further to a multiple reduction in energy costs during melting in the furnace at least 1.5 times more.

At the stage of dissolution of the silicate block in water, an autoclave-free technology is provided, in which the finely ground silicate block is dissolved in water at normal pressure,

which reduces energy consumption compared to the traditional technology of dissolution in superheated steam at high pressures.

The cost of water vaporization is 2260 kJ/kg, so the specific heat required for heating water from 0 to 98 degrees Celsius is only $4.1 \times 98 = 401$ kJ/kg.

That is, the amount of energy required for water vaporization, taking into account that the steam still needs to be heated to 150 degrees with traditional technology compared to the proposed 6 times more.

The main problem in the production of sodium silicate is high capital intensity and high energy intensity.

The authors are working in the field of reducing energy costs. For this purpose, the technology of reactive power compensation with a magnetic amplifier is proposed, which is key, can be used in hundreds and thousands of companies only in Kazakhstan, where there are significant unit costs for electricity – from mining to street lighting.

In a broad sense, reactive power compensation technology with a magnetic amplifier can be used not only for melting sodium silicates, but also in metallurgical furnaces, mining farms, electrolysis workshops, and municipal lighting. The technology of reactive power compensation with a magnetic amplifier is currently tested and used in Turanga LLP (Almaty) in industrial conditions at a wood thermating plant with a capacity of 150 kW. It is planned to apply the same technology in the melting of sodium silicate in an electric furnace with a capacity of 1MW.

4. Conclusions

The most likely to be used under the conditions of the task is the processing of natural sodium sulfate. However, in terms of availability, this type of raw material, despite its widespread distribution in Kazakhstan, is not suitable for solving this problem, since no one has the rights to extract it.

Therefore, the processing of recycled glass, now unclaimed by the domestic industry, can be a source of raw materials for the production of silicate blocks with a given cost at the level of 28-30 thousand tenge per ton.

The engineering and technical embodiment of melting can be cyclone melting, provided that the issue of waste gas purification is resolved, as well as melting in electric furnaces, provided that energy savings are ensured.

Sodium silicate, produced in the form of a silicate block by Russian enterprises, is currently imported to the Republic of Kazakhstan, where it is dissolved in water and further used at enterprises of the construction, corrugated cardboard and, mainly, metallurgical industry.

The most tonnage direction for the sale of sodium silicate could be the sector of production of polymer cements and concretes. The main problem in the production of non-roasting, non-clinker binders obtained on the basis of waste from steelmaking enterprises (granulated blast furnace slag) is the lack of inexpensive primary or secondary alkaline materials on the market that can not only activate such binders, but also match the low price of traditional Portland cement.

Thus, the introduction of the proposed technology will allow not only to start a solution for import substitution, but also to indicate a technical solution for involving tens of millions of tons of Temirtau and Taraz slag into economic turnover, which will reduce carbon dioxide emissions by reducing the production of Portland cement, which currently produces almost more carbon dioxide in rotating coal furnaces, than the cement itself.

In addition, the project provides for the production of sodium silicate not from quartz raw materials and soda, but from secondary glass and soda, since there is already a high amount of required sodium oxide in the cullet.

Another difference between the project and the traditional ones is the use of an electric furnace equipped with a reactive power compensation unit with a magnetic amplifier, which will

make it possible to reduce the specific amount of electricity by at least 2 times.

The second technical difference is the technology of dissolution of sodium silicate. Traditionally, sodium silicate is dissolved in water in autoclaves at high vapor pressure, which is too energy-consuming. In our case, the silicate block is crushed and dissolved in water at a temperature of 95-98 degrees Celsius at normal pressure. At the same time, an energy-efficient device is used, protected by patent No. 2397 with the authorship of one of the team members – T. S. Dauletbakov.

But the most important consequence of the project is the practical expansion of reactive power compensation technology with a magnetic amplifier, which in the future can be used in all power grids with a significant reduction in energy consumption and ultimately significantly affect the decarbonization of the industry of the Republic of Kazakhstan.

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ORCID iDs

K K Yelemessov <https://orcid.org/0000-0001-6168-2787>

D D Baskanbayeva <https://orcid.org/0000-0003-1688-0666>

L B Sabirova <https://orcid.org/0000-0001-8231-9944>

Sh D Akhmetova <https://orcid.org/0000-0003-3556-3818>

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