PRODUCTION OF GLASS CONTAINERS BASED ON THE CONDITIONS OF THE REPUBLIC OF KARAKALPAKSTAN

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Abstract. *This article discusses the economic and technological foundations of establishing glass production in the Republic of Karakalpakstan, taking into account the mineral and mineral resource conditions. Information is provided about the main technological and chemical processes in the production of glass containers. Also, during our research, the main sources of raw materials, energy and logistics factors, environmental requirements and market needs in glass production were analyzed and feedback was given. During the article, we made proposals based on practical research on the production of glass products.*

Keywords: *Minerals, glass containers, glass industry, technological processes, energy efficiency, chemical processes, ecology, production technology.*

QORAQALPOG'ISTON RESPUBLIKASI SHART SHAROITIDAN KELIB CHIQQAN HOLDA SHISHA IDISHLAR ISHLAB CHIQARISH

Annotatsiya. *Ushbu maqolada Qoraqalpog'iston Respublikasida minerallarning, foydali qazilmalarning joylashish shart-sharoitidan kelib chiqqan holda shisha idishlar ishlab chiqarishni yo'lga qo'yishning iqtisodiy va texnologik asoslari yoritiladi. Shisha idishlarini ishlab chiqarishdagi asosiy texnologik jarayonlar va kimyoviy jarayonlar haqida ma'lumotlar berib o'tiladi. Shuningdek, tadqiqotimiz davomida shisha ishlab chiqarishda asosiy xomashyo manbalari, energiya hamda logistika omillari, ekologik talablar va bozor ehtiyojlari tahlil qilingan holda mulohazalar keltirib o'tiladi. Maqola davomida shisha mahsulotlarini ishlab chiqarsih bo'yicha amaliy tadqiqotlarga asoslangan holda takliflarni berib o'tganmiz.*

Kalit so'zlar: *Minerallar, shisha idishlar, shisha sanoati, texnologik jarayonlar, energiya tejamkorlik, kimyoviy jarayonlar, ekologiya, ishlab chiqarish texnologiyasi.*

Introduction

The Republic of Karakalpakstan is located in the northwestern part of Uzbekistan and has unique conditions in terms of natural resources, transport corridors, production infrastructure and, most importantly, the environmental situation (Aral Sea). In such conditions, resource efficiency, logistics costs, energy efficiency and environmental safety remain the main criteria for choosing production sectors. Glass containers (bottles, jars, food and pharmaceutical packaging) are considered one of the promising areas in Karakalpakstan as a product with high recyclability, inertness, meeting sanitary requirements and having the potential to replace imports. This article systematically discusses the justification of glass container production based on regional conditions, raw material and energy sources, technological chain, market demand, logistics, environmental and socio-economic impacts. The climate of Karakalpakstan is sharply continental: summers are hot and dry, winters are cold, and winds can be strong. Such conditions increase energy consumption (especially heating, cooling and dust protection) in industrial plants, but costs can be significantly reduced through proper industrial design - thermal insulation, recovery systems, filters and closed-cycle cooling.

The settlements and industrial nodes of the region (economic activities around the cities of Nukus, Khojaly, Kungrad, transport routes) create the main infrastructure for the location of production. Three factors are important in the production of glass containers: a stable energy supply, a raw material base and logistics that allow for the rapid delivery of products. The presence of routes to both the domestic markets of the republic and to Kazakhstan and Turkmenistan through Karakalpakstan increases export and transit potential. Especially in the context of the development of consumer goods and the food industry, the production of glass containers strengthens the local packaging chain: there is a constant demand for containers in the drinking water, juice, dairy products, canned goods, oil and grease, pharmaceutical and cosmetic industries. Glass is a chemically inert material: it does not change the taste of the product, does not absorb odors, does not cause the problem of microplastics, and can be recycled many times.

Since Karakalpakstan is a region with a high ecological burden as part of the Aral Sea region, an ecological approach to packaging (the use of recyclable, long-lasting materials) is of strategic importance. If the production of glass containers is organized in conjunction with a recycling system, it is possible to reduce waste and expand the economic value chain: the glass cullet mixture reduces the furnace temperature, reduces energy consumption, and reduces the consumption of raw materials (sand, soda, limestone). Also, if there is a dependence on the import of glass containers, local production saves foreign exchange. The container itself often has a significant share in the cost of the product; therefore, localization of packaging increases the competitiveness of the beverage and canning industry. Therefore, glass containers should be viewed not only as a "single plant" issue, but as the basis of the entire food and pharmaceutical ecosystem. Glass production is mainly based on lime-silicate glass, which has three main components: (1) silica source (SiO_2) - quartz sand; (2) solvent - soda ash (Na_2CO_3) or sodium sulfate; (3) stabilizer - limestone/dolomite ($CaCO_3$, $MgCO_3$). In addition, aluminum oxide, coloring agents (iron oxide - green / brown), clarifying additives and cleaning agents are used. In the conditions of Karakalpakstan, the issue of quartz sand is of strategic importance: the proportion, purity (Fe_2O_3 content), moisture and organic impurities of sand directly affect the quality of glass. If sand reserves for industrial demand are limited in the region itself, it can be supplied from other regions of the republic or neighboring regions in a material and technical way. An important aspect is the continuity of raw material supply: if a furnace stops, restarting it will result in significant losses, so the storage capacity and contractual supply must be reliable.

Collection and sorting of recycled glass cullet makes the raw material base cheaper. In large settlements and trade networks of Karakalpakstan, a deposit system can be introduced: the consumer is encouraged to return an empty container, and the manufacturer receives high-quality cullet. If the share of cullet is increased to 30-60%, energy consumption and CO_2 emissions will be significantly reduced. However, this requires a sorting line (by color, separation of metal and ceramic impurities) and a logistics network.

Effective solutions in the conditions of Karakalpakstan. Glass production is an energy-intensive process: melting in a furnace is usually around 1450-1550 ° C. Natural gas, electricity (electricity), sometimes fuel oil or alternative fuels (biogas, hydrogen mixtures) are used as energy sources. In Karakalpakstan, the stability of energy supply, gas pressure and continuity of power grids are among the most important conditions. At the same time, energy-saving solutions - regenerative or recuperative furnaces, waste heat recovery and increased efficiency of hot air combustion - reduce costs and reduce atmospheric emissions.

Water resources are also important: in the production of glass containers, water is mainly needed for cooling circuits, compressors, mold cooling and some technological washing processes. Since the principle of rational use of water is relevant in the Aral Sea, a closed-loop cooling system, cooling towers, water refiltration and the concept of zero/low flow are recommended. This is not only an environmental requirement, but also beneficial for production sustainability: water shortages should not stop the plant from operating. In Karakalpakstan, as in the Uzbek market in general, the need for beverages, canned goods, import-substituting packaging materials is growing.

Although glass containers are heavier than plastic and have higher transportation costs, glass is preferred in the high-quality segment, for products with a long shelf life and in industries requiring sterile packaging. In addition, when glass containers are operated with a "return" model (circular container), logistics costs are partially offset. As the production of products such as drinking water, juice, milk, kefir, yogurt expands in the region, the need for glass containers will increase even more. Also, proximity to the neighboring Kazakh market can create export opportunities, but the standards for export (dimensional tolerances, strength, food safety, labeling) are strict. Since glass containers are heavy and fragile, they occupy a significant part of the transportation costs. When placing the plant, two flows are taken into account: the input of raw materials (sand, soda, limestone, cullet) and the output of finished containers. Whichever flow is heavier and has a longer distance, the closer the plant is to this flow. In practice, glass plants are often built close to large consumers (beverage plants, canning clusters), since there is a risk of damage to the finished container and the problem of "air transport" (empty volume).

Therefore, it is advisable to locate the enterprise in Karakalpakstan, close to the industrial and logistics hubs of Nukus and its surroundings, and to ensure its connection with railways and highways. Storage is also a separate issue: containers are stored on pallets, wrapped in shrink film; the warehouse must be dry, dust-proof, vibration-proof and shock-proof. Given the dry and dusty climate of Karakalpakstan, warehouses are equipped with filtered ventilation, floor coverings, and lifting devices for lifting loads. Since container breakage and defects are common losses in the logistics process, the standard of packaging and transportation is as important as the production itself. The uninterrupted operation of a glass factory is impossible without qualified personnel and a strong maintenance system. Furnace operators, batch mixing specialists, IS machine adjusters, molders, laboratory and quality control engineers - all of these require special skills. Short courses, internship programs, and a dual education model can be established in cooperation with local vocational centers, technical schools, and higher education institutions to train personnel in Karakalpakstan. This will not only meet the needs of the enterprise, but also create sustainable employment and increase the engineering culture in the region.

The quality of glass containers is assessed by several indicators: geometric dimensions (height, diameter, neck, mouth), weight resistance, wall thickness, internal stress (with a polaroscope), mechanical strength (pressure resistance), thermal shock resistance, defects (bubbles, stones, cracks, seam traces). When setting up production in Karakalpakstan, it is advisable to gradually introduce a laboratory base and an online inspection system (cameras, laser measurement). In particular, the beverage industry operates on high-speed filling lines; even a small defect in the container can lead to a failure. Therefore, technical specifications (TS) are clearly agreed between the manufacturer and the consumer (bottling plant). Export planning also includes tests for compliance with international standards, traceability (batch number, date of manufacture), packaging and transportation.

For the local market, hygiene requirements are also important as a food contact material: the container must be free of foreign particles, odors, and be suitable for washing/sterilization processes. These issues require the establishment of a quality management system (e.g. ISO approaches) from the very beginning of the plant. A glass factory can demonstrate environmental responsibility at two levels: minimizing waste from the production process, developing a packaging and recycling ecosystem. Glass furnaces can emit NOx, SOx (depending on fuel and raw materials), dust and sometimes fluorine compounds.

To reduce this, filtration systems (bag filters, electrostatic precipitators), low-NOx combustion devices, proper raw material selection and monitoring (gas analyzers) are needed.

Increasing the cullet fraction also reduces emissions, as the melting temperature and energy consumption are reduced. Technical measures are taken to use water in the production area, mechanical and chemical treatment of wastewater, and the use of a closed loop to suppress dust. In addition, cullet and defective products are not “waste”, but a resource that can be remelted. Collecting glass from household waste reduces the amount of waste going to landfills.

This makes a small but systematic contribution to reducing the environmental burden in the Aral Sea region: the industry carries a socio-ecological responsibility along with economic benefits. A glass bottle factory requires significant capital: a melting furnace, molds, an annealing furnace, compressors, a laboratory, filters, automation, a warehouse and logistics. The size of the investment varies significantly depending on the capacity and type of product.

Therefore, the most optimal way in the conditions of Karakalpakstan is to develop it gradually: first, a type of container for which there is a clear market, then increase the capacity and expand the assortment. Another way is to conclude "offtake" contracts with large consumers: manufacturers of beverages and canned goods guarantee a certain volume, and the plant reduces the investment risk. Risks include energy prices and continuity, raw material logistics, spare parts for equipment, staff shortages, market changes. To mitigate these, energy-efficient furnaces, cullet collection systems, backup power (generator/power supply stability), service contracts, staff training programs, and market diversification (canned + bottled) are recommended. For example, if drinking water and juice producers, canneries, logistics operators, waste collection companies, packaging (caps, labels) suppliers, and laboratory services are in one system, costs will be reduced. A cluster approach in Karakalpakstan can boost the regional economy: on the one hand, packaging is localized, and on the other, additional jobs and service services are developed. In particular, cooperation with the production of caps (metal/plastic), labels, and cartons completes the finished product chain and reduces dependence on external supplies.

Conclusion

In the conditions of the Republic of Karakalpakstan, the production of glass containers is an economically and environmentally sound direction: it relies on recyclable materials, has a stable demand in the food and pharmaceutical industries, allows for import substitution and strengthening regional cooperation. However, the key to success is the efficient use of energy and water resources, the establishment of a system for collecting and sorting cullets, the proper organization of logistics and warehouses, strengthening quality control, and personnel training.

The ecological sensitivity of the Aral Sea region requires the development of the glass industry based on a more responsible and “green” approach; only such an approach will make the production of glass containers a long-term, sustainable and profitable industrial direction for Karakalpakstan.

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