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Estimation of Production Efficiency for Integrated Processing of Lithium-Containing Raw Material

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Abstract

Economic efficiency was investigated for the integrated use of lithium-bearing raw material. The versions of industrial arrangement are considered for two kinds of raw material such as hydromineral and mining one, differing in logistics and completeness. It is demonstrated that the use of hydromineral raw material allows substantially decreasing the risks connected with the reduction in demand for auxiliary products; as well as allows one enhancing the competitiveness of production at the expense of cost saving for separate products in the course of the integrated extraction of useful components of brines in a united industrial cycle.

Key words: spodumene ores, hydromineral raw material, integrated processing, economic efficiency

The application fields of lithium are manifold and increasingly expanding. The structure of the consumption of lithium products has undergone significant changes for recent years. The time of innovations has pressed the traditional application fields of lithium and its compounds in the aluminium-and-lithium manufacturing, in producing glass and ceramics, in organic synthesis, in the manufacture of greases, thermoplastic elastomers, *etc*. In world practice, there is increasing the role of other application fields of lithium and its compounds such as the production of chemical current sources with lithium conductivity, manufacturing ultra-light alloys based on aluminium, magnesium doped with lithium for aerospace engineering, pharmaceutical manufacturing. Table 1, compiled basing on data from [1] demonstrates the structure of the consumption of lithium products in the world (for 2010).

Extending the application fields of lithium compounds promoted the development of branches producing lithium from different raw materials. For example, in 2008 the volume of lithium carbonate production in the world has been doubled as compared to previous decades.

However, in Russia, the consumption of lithium carbonate in 2007–2008 decreased to a significant extent amounting to about 345 t in 2009 (1002 t in 2007), which is caused by the absence of own raw materials source for manufacturing primary lithium products. In Russia there is currently no manufacturing the lithium products both from mining products (after decommissioning the Zavitino spodumene mine) and from hydromineral raw materials, whose processing is considered to be the most economical.

The main supplier of lithium carbonate to date is presented by so-called Lithium triangle of the South America, covering the three salt deserts: the Atacama (Chile), the Uyuni (Bolivia), and the Omre Muerto (Argentina). There are 70 % of all available world reserves of lithium concentrated in this territory. However, the rapid development of the salt lakes in Qinghai Province (China) could soon break the monop-

TABLE 1

Consumption structure of lithium products in the world, % [1]

Fields of consumption	Companies	
	SQM (Sociedad Quimica y Minera de Chile S.A., URL: http://www.sqm.com)	Roskill (Roskil Information Services Ltd., URL: http://www.roskill.com)
Glass and ceramics industries	29	30
Production of chemical current sources	27	22
Manufacture of lubricants	12	12
Production of air conditioners	4	5
Production of polymers	3	4
Production of drugs	2	2
Production of aluminium	2	2
Other*	21	23

* Alloys, building materials, dyes, industrial hygiene, specific inorganic compounds.

oly of the South American continent. Conventionally variable outlay in the cost price of lithium carbonate produced from salars in Atacama (Chile) is about three times lower comparing to the outlay in the case of mining raw materials. This could be explained by a high energy and materials consumption of the technology and a high outlay of mining and refining the spodumene ore. At present, the issue of obtaining the lithium carbonate from domestic raw materials is especially urgent.

In 2010, the Thunder Sky Co. (China) and the RUSNANO JSC signed in Peking a package of documents for establishing of the first in Russia works of lithium-ion batteries in Novosibirsk. It is assumed that the synthesis of the cathode material will be performed in Russia. For this purpose, by 2013 it is planned to perform an import substitution of Chilean lithium carbonate by domestic one. The RUSNANO JSC is ready to support the project submitted by Ecostar-Nautech Ltd. concerning the development domestic manufacturing lithium carbonate from salines, but under the assumption of the availability of an investor interested in. TVEL Fuel Co. of the Rusatom Overseas JSC serves, of course, as such an investor in Russia.

The development of new non-traditional domestic lithium-containing raw materials those provide a cost-efficient manufacture of lithium products represents the most important task, whose accomplishing could allow not only stabilizing the manufacture of lithium products in Russia, but also achieving any progress in this area.

In this case, the only type of a raw material that allows obtaining competitive lithium products should be presented by a domestic hydromineral lithium-containing raw material in the form of deep stratal brines, drainage brines from the diamond quarry of the Udachnaya kimberlite pipe and associated oil waters of calcium chloride and calcium-magnesium type.

The brines of this type are characterized by a high ratio between the sum of Ca and Mg concentrations and the concentration of Li ($R = 190-470$); they are distributed in the eastern part of Russia, in the northwest of China, as well as in Turkmenistan and in Israel.

Cost-efficient processing the Russian lithium-bearing hydromineral raw (LHMR) into commercial lithium products is not possible with no preliminary enrichment. The process of enriching the LHMR should be reduced to the development of methods and techniques those allow extracting lithium from salines with no use of reagents in the form of lithium chloride solutions with $R \leq 15$ in order to further possibility of concentrating them with respect to lithium by means of either method.

Taking into account the multicomponent composition of LHMR, the economic indices of manufacturing the lithium products could be significantly improved at the expense of the organization of associated production of commercial products basing on extracting, alongside with lithium, other valuable components [2].

The manufacture of lithium products from natural brines basing on the reagentless sorption-based enrichment with respect to lithium could be harmoniously fitted within the framework of the technology of integrated processing the LHMR with a complete utilizing the salts present in the saline. This could allow one to obtain valuable products parallel or in series, such as bromine, lithium bromide, magnesium oxide, as well as large-tonnage products such as anti-glaze material (ice melter) based calcium and magnesium salts (AGCM), lithium-fluoride containing complex salts, magnesia-based binding agents, antifreeze additive for concrete as well as a base-stock for drilling fluids and grouting mortars [3].

The primary products obtained from the lithium concentrate and from the brine after enrichment, could be used for the production of salts and materials applied in various fields of engineering, including novel materials (Fig. 1).

Another kind of lithium-bearing raw is presented by mining raw materials. Russia has a large number of ore deposits and heaps resulting from enriching rare metal raw materials those exhibit poor lithium content; they can be used in the case of cheap ways to recover.

In order to improve the economic efficiency of processing them, researchers have developed a simplified version of the lime method for processing crude spodumene ore [4]. It should be noted that the spodumene concentrates were the only source of raw materials for obtaining lithium products up to the 90ies of the last century.

In order to simplify the process of opening lime spodumene ore species without enriching them, the existing technology of processing the spodumene concentrates was amended as it follows:

1) decreasing the amount of limestone in the charge mixture (from 3 to 2.2 mol CaO per 1 mol of SiO_2) in the course of the mixture sintering under the lithium repartition;

2) introducing soda into the charge mixture for binding sodium and potassium into soluble aluminates;

3) replacing the operation of the evaporation of alkali metal hydroxide solution of (Li, Na, K) by a simple operation consisting in the deposition of double aluminum and lithium hydroxide $LiOH \cdot 2Al(OH)_3 \cdot 5H_2O$ (DHAL-OH) from aluminate solution;

4) providing the opportunity of producing cement from lithium production waste (sludge).

These modifications are aimed at reducing the material flows to the operations of obtaining the lithium products and at the simultaneous extraction of lithium and aluminium, on the one hand, as well as at the subsequent utilization of waste for the production of lithium cement, on the other hand. The results of the studies performed, and of integrated pilot testing the technology, as well as of determining any possible ways to use double aluminium and lithium hydroxide, were summarized in [4]. The further development of the technology, mainly concerning the lines of using binary aluminium and lithium compounds, as well as exploring novel aspects of developing the technology for improving the method of processing crude spodumene ore species were published in [5].

At the present time, the technology of processing of aluminosilicate materials with a low content of Li_2O could appear under demand [6]. Owing to the growth in the volume of con-

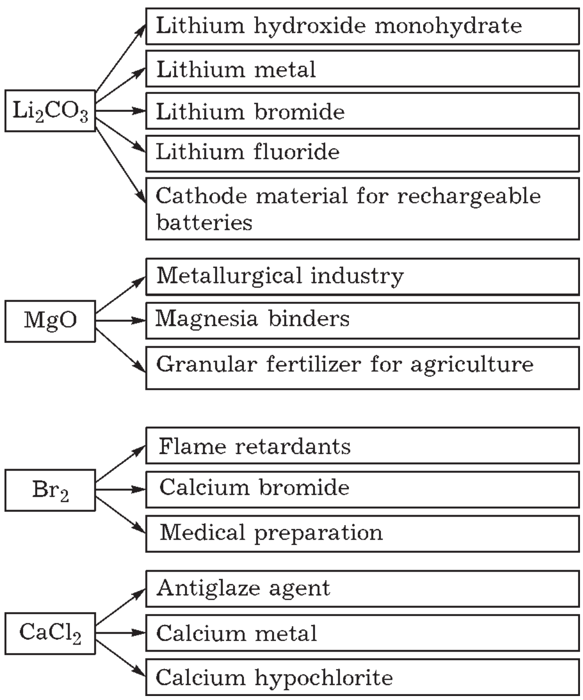

Fig. 1. Main primary products obtained from brine, and the fields of application.

struction in recent years, there appeared an urgent problem of obtaining cement. As shown by the authors of [5] the lithium manufacture wastes containing the major components of the cement clinker (dicalcium silicate, calcium aluminates and alumoferrites), with appropriate adjustment could be an excellent raw source for both sludge cement and Portland cement [5, 6].

We considered variants for the organization of production for the two types of lithium-bearing raw materials such as ore-mining and hydromineral ones those differ each from other in logistics and completeness.

The annual output of LHMR is equal to3800 thousand m^3, the raw material exhibits the following composition (kg/m^3): LiCl 2.4 (or Li 0.4), NaCl 15, $MgCl_2$ 115, $CaCl_2$ 330, Br 9. The annual output of lithium from the LHMR amounts to 1520 t. Given the same amount of lithium obtained the average composition of the spodumene ore (annual output 400 t) can be presented as it follows (mass %): Li_2O 0.82 (Li 0.38), Na_2O 3.9, K_2O 1.96, Al_2O_3 15.9, SiO_2 73.3.

Table 2 demonstrates the indicators of the economic efficiency of integrated processing the LHMR from the Kovykta deposit and the Tashelga spodumene ore deposit [6]. In this case for the comparison there are two variants chosen are similar to each other with respect to lithium content in the raw material: for LHMR it is the variant with obtaining technical grade lithium carbonate and lithium-containing fluorides, whereas for ore processing it is the variant with on-site obtaining double aluminium and lithium hydroxide, with further transporting it to the Chemical and Metallurgical Plant JSC (Krasnoyarsk) to process the double hydroxide into lithium hydroxide monohydrate .

The complexity of the raw material processing in these cases were provided by the fact that, in addition to lithium products in the first case a portion of the saline extracted served as a source for producing an antiglaze agent. In the latter case, the sludge resulting in the course of manufacturing the lithium products was used to produce cement clinker at a cement plant located nearby to the deposit.

It should be noted that both projects are cost-efficient, whereas the project of spodumene raw processing seems to be more preferable according to the standardized efficiency indicator (net discounted profit).

It should be noted that utilizing single lithium products in both projects cannot bring the manufacture in full payback. The efficiency is based on an auxiliary product such as cement, whereby the production of lithium from ore looks economically preferable. In case the production of lithium considered principal, the ratio between cost percentage values of pri-

TABLE 2

Economic indicators for the projects of processing lithium-bearing hydromineral raw (LHMR) and spodumene ore

Indicators	LHMR	Spodumene ore
Annual output of raw material (brine, ore) (thousand m^3, kt)	3800	400
Annual output (kt):		
antiglaze agent	400	–
technical grade lithium carbonate	3.6	–
lithium-containing fluoride salts	11.06	–
lithium hydroxide monohydrate	–	7.9
cement	–	920
Annual volume of sales (million roubles)	3083	4429
Including lithium products	1483	748,0
Capital outlays (million roubles)	1365	2409
Annual operating costs (million roubles)	761	1210.5
Average annual net profit (million roubles)	1751	2450
Net discounted profit of the project (million roubles)	7605	7998
Internal rate of the project profitability (%)	116	81.9
Payback period (years)	2.5	2.7

mary products (lithium compounds) and auxiliary products (antiglaze agent and cement) for manufacturing from LHMR amounts to 48/52, whereas for manufacturing from the ore this ratio is equal to 17/83.

A high proportion of auxillary products determines the sensitivity of the project to the risks of changing in demand. With falling the demand and the prices of cement products there is a significant decrease in the profitability of the production, up to the unprofitableness. In this case decreasing the production of cement is automatically connected with a compelled reduction in manufacturing the lithium products, even with increasing the demand for them.

At the same time, the use of hydromineral raw materials allows one to a significant extent reduce the risks associated with the recession in demand for a supporting product such as antiglaze agent, ice melter. The calculations demonstrate that even a two-fold decrease in the volume of ice melter production insignificantly reduces the efficiency of the project. The net discounted profit exhibits a decrease down to 4.444 billion roubles, whereas the payback period increases up to 3.5 years. In addition, as demonstrated in [2, 3], the complexity of minerals extracted from brines could be enhanced, to obtain lithium bromide and pure bromine, magnesium products and magnesia binders in addition to lithium carbonate and lithium fluoride salts of (such as, for example, it is done at the Kovykta deposit). In this case, according to the indicator of net discounted profit, the manufacture of lithium products from LHMR appear more efficient than the manufacture from spodumene raw materials, whereas capital outlays and operating costs, though increasing in comparison with an alternative variant of obtaining lithium carbonate, fluoride salts of lithium and antiglaze agent, remain nevertheless lower than the corresponding indicators inherent in the production from ore raw.

The organization of production based on comprehensive extracting different products from LHMR, provides also the growth of business stability at the expense of diversifying the product set. This allows one to improve the competitiveness of the production at the expense of reducing the production cost for separate products in the course of complex extracting the useful components from salines in a single processing cycle. Such an integrated processing flowchart provides the possibility of a serial-parallel extraction of useful components as the entire complex become ready to the commercial operation, as well as the reorganization of production in accordance with changes in the market requirement for the products.

In addition to the deep-seated brines of the Irkutsk fields, whose development involve high expenses for borehole drilling, there are other sources of hydromineral raw materials those do not require borehole drilling. These raw sources include drainage salines from diamond deposits (Yakutia). The drainage brines of the Udachnaya kimberlite pipe every day bring to the surface up to 5400 kg of lithium chloride [7]. With using them, the amount of capital outlays could be reduced to a significant extent.

Basing on the analysis of economic indicators and taking into account the trend of the world's manufacturers of lithium products, the prospects for the manufacturing of primary lithium products in Russia should be connected with the involving the hydromineral sources of raw materials, whose processing technology is always ready for commercial development with obtaining competitive lithium products.

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