East Transbaikal zeolite production: Potential and integrated Ecological safety

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Abstract. The author discusses resource potential of zeolite-bearing rocks in East Transbaikal with regard to geoecological safety of mining and processing. The role of climate in the environmental impact of zeolite production is identified. Potential activities aimed to reduce anthropogenic load on the environment are proposed.

1. Introduction
Russia holds huge zeolite reserves in more than 70 deposits and occurrences. Ultimate proven reserves of zeolite-bearing rocks make 25 Bt at average zeolite content of 25–35% [1]. The largest deposits of zeolite are found in the Krasnoyarsk Krai (Pashenka, Sakhapta, Voznesenka), in the Irkutsk Region (Badarma), Kemerovo Region (Pegas), Transbaikal and Buryatia (Shivyrtui, Khola, Bada, Talan-Gozagor), in the Primorskii Krai (Sereda, Chugui), on the Sakhalin Island (Lyutoga, Chekhov) and in Yakutia (Khonguruu, Soros, Chuchuba) [1].

Transbaikal offers a higher potential for zeolite supply. Thus far the region contains four large and twenty medium-size zeolite-bearing bodies. Their geography is favorable, including transportational routes and developed areas. The deposits of the highest commercial interest are Shivyrtui, Khola, Bada and Talan-Gozagor which hold in aggregate 17 Bt of zeolite reserves [2].

Transbaikal’s deposits of natural zeolites are mostly represented by clinoptilolite, mordenite and chabasite widely applicable in industry due to their properties. Currently only the Khola deposit is in operation and supplies zeolite highly demandable in medical industry, agriculture and in adsorption technologies. The Shivyrtui deposit is suspended though its zeolite products found ready market in yesteryear. The Bada deposit contains much cancerogenic mordenite and is therefore left virgin. The Talan-Gozagor occurrence holds the most valued type of zeolite—chabasite, but is yet held in expectation of commercial development.

High hopes are laid on zeolite resources of the Priargunsk Region in Transbaikal in view of the decision made by the Government Commission and Monotown Development Foundation to approve the status of Krasnokamensk as the Territory of Advanced Social and Economic Development. In the nearest future, in accordance with the Transbaikal Zeolite program, it is intended to include the Shivyrtui and Talan-Gozagor zeolite mining projects in the monotown development plan to provide the region with quality feedstock to produce outputs applicable in medicine, environmental technologies, construction, agriculture, etc. The available industrial facilities for zeolite-bearing rock processing (at present suspended) in the town of Krasnokamensk can assist in building a full-scale integrated works on treatment and processing of Shivyrtui and Talan-Gozagor zeolite to manufacture marketable products.
Zeolite mining and processing in the Krasnokamensk area can promote industrial and social infrastructure but also can exert extra environmental impact. The ecological implementations can include ecosystem disfunctioning, air, soil and surface/underground water pollution and landscape damage. The heaviest and the largest size environmental impact is exerted on land (partial or total elimination, deforestation, soil disturbance, etc.) and fauna [3].

2. Features of the development and processing of zeolite-bearing rocks

The adverse effect of mines is limited by their direct influence zone, which can be minimized in case of proper and effective environmental activities. Sever impact exerted by a mine on the adjacent area necessitates integration of the environmental activities with resource-saving technologies to be introduced in all production cycles, from extraction of minerals down to manufacture of final marketable products. Effective utilization of zeolite requires that processing involves direct treatment by energy and mechanical attacks, or chemical treatment by acids or alkalis (manufacturing of aluminum-containing products), which entail grave environmental damage.

An important factor is the implementation of effective waste management after zeolite mining. Considering the local geography, as well as the industrial development and infrastructure in the region, zeolite production waste can be used in construction, in backfill preparation for mines, road building, etc. The comprehensive approach to waste management can allow total elimination of waste storage on special sites and, thereby, enable reduction of anthropogenic load on the environment. For another thing, avoidance of dumps and tailings ponds makes it unnecessary to undertake measures and to spend money for waste disposal, or protection from weathering, oxidation, etc. The processes of mineral mining and processing, as well as marketable product output should be integrated within a single closed technological loop, which is only possible when waste of an industry is used as a feedstock in the other industry. The process flow design for zeolite processing should be based on the principles of wasteless production, with transition from concentration to disaggregation of zeolite-bearing material. This approach should be implemented at all stages of zeolite mining, with selective separation of types and grade suitable for further application. Some types and grade of zeolite-bearing rocks are usable without preliminary treatment (in case of zeolite content of 95–98%). Regarding the zeolite deposits discussed in this paper, the reserves feature low content of valuable component (zeolite). Thus, it is required to develop and improve technologies of zeolite concentration and removal of impurities. These technologies should ensure efficient zeolite processing, be resource saving and minimize the environmental impact.

Wide application of zeolites is constrained by law quality of initial raw material which needs beneficiation. The main processing methods can be gravitational, magnetic and electrical separation aimed at physicochemical modification and activation of zeolite-bearing rock properties.

In view of the known and newly developed mechanisms of zeolite-bearing rock processing, there are the preparation cycle and the main cycle. The preparation cycles includes crushing, milling, preliminary treatment by ultrasound, drying, mechanical and mechanochemical treatment, hydrochemical treatment, energy input, screening and dedusting.

During the main processing cycle, all iron-bearing, impurities, minerals of quartz and feldspar are totally removed from zeolite by means of magnetic and electrostatic separation. Electrostatic separation is an efficient technique meant to remove minerals of quartz, mica and feldspar from zeolite-bearing rocks, and the use of salicylic or benzoic acids for 30–60 min to impart contrast attributes to the constituents ensues total removal of all listed impurities from mineral particles – 0.074 + 0.5 mm.

The special physicochemical operations included in the processing circuit of zeolite-bearing rocks involve treatment by salicylic or benzoic acids to stimulate electrostatic separation, hydrochemical activation and intense electromagnetic exposure. These physicochemical operations are only necessary to implement directed physicochemical modification of properties of zeolite as consistent with the industry standards.
The preparation cycle of zeolite-bearing rock processing should include mechanical or mechanochemical treatment. One of the most effective preparatory techniques is ultrasonic treatment to improve separation of zeolite and impurities (feldspar, montmorillonite, quartz, plagioclase, etc.), which ensures the highest productivity of magnetic and electrostatic separation. The ultrasonic field energy enhances dispersing owing to point erosion of solid surface of phase boundary and accelerates concentration of zeolite. Ultrasonic treatment also improves separation of clay component. It is found that ultrasonic treatment should be carried out at a frequency of 22 kHz. In this case, the number of scavenging circuits in the process flow chart is reduced, and the content of zeolite in the concentrate increases to 85–95%. The IR-spectrum analysis of zeolite-bearing rocks shows the increased zeolite content in samples treated by ultrasound. The review of the foreign and Russian experience of zeolite processing using various methods is summarized in Table 1.

**Table 1. Basic methods of zeolite concentration subject to mineral composition of rocks**

| Mineral to be extracted | Associate minerals | Method of concentration |
|------------------------|-------------------|------------------------|
| Zeolite, chabasite     | Feldspar, Mica > 50 µm | Rotary crushing and ball milling, Mechanochemical treatment, Ultrasonic treatment, Hydrochemical activation, Directed effects, Magnetic separation with permanent magnets or electromagnetic separation in isodynamic field, Electrostatic separation, Ultrasonic treatment, Magnetic separation, Electrostatic separation with heating electrization, Rotary crushing and ball milling, Mechanochemical treatment, Ultrasonic treatment, Hydrochemical activation, Directed effects, Electrostatic separation |
| Clay minerals < 50 µm  |                   |                        |
| Zeolite, chabasite     | Minerals of quartz, clay minerals | Ultrasonic treatment, Hydrochemical activation, Directed effects, Electrostatic separation |

When the associate minerals are mainly from the group of feldspar and mica with other subordinate associates, it is expedient to use magnetic separation and electrostatic treatment. When zeolites in mineral aggregates are smaller than 50 µm, electrostatic separation should include heating electrization with steams of salicylic or benzoic acids, followed by electromagnetic separation to remove iron impurities. The combination of electromagnetic and electrostatic treatment considerably reduces amount of associates and increases zeolite recovery to 80–90%.

The processing flow chart design should take into account the fractional makeup and physicochemical properties of zeolite-bearing rocks, and interaction between the separation abilities of host minerals and the valuable component content in the initial raw material. The methodology of development and selection of process flow charts for zeolite-bearing rocks and the equipment configuration should be based on the criteria of optimality—safety, maximum extraction of useful...
component from subsoil and efficient subsoil management. The new process flow charts intended to modify properties of zeolite-bearing rocks include: mechano-chemical (mechanical deformation) treatment, ultrasonic treatment before screening, fine cleaning to remove iron impurities, electrostatic separation of nonmagnetic impurities, subject to directed effects and hydrochemical processing.

The area of Shivyrtui and Talan-Gozagor zeolite deposits is a large industrial hub. Sustainable ecological equilibrium requires an in-depth analytical study of the environmental impact of zeolite production activities, forecast of environment alterations and reasonable environmental measures in compliance with the anthropogenic attack specificity and the response of nature to it. The nature-oriented activity management should prioritize the region-specific criteria and poor resistance of natural systems to human intervention in order to prevent instability, structural damage and malfunction of eco-systems.

It deserves explaining that weak survivability of natural systems is partly governed by severe local climate in the Priargunsk Region. The climate is continental, the yearly average air temperature is -2.2°C, the yearly mean wind speed is 1.3 m/s, with dry summer and with little snow and heavy frost in winter. The area of the planned production is a flat terrain, which provides good atmospheric dispersion of industrial emissions without their concentration in the ground layer nearby inhabited localities. All these factors, including the continental climate, long and cold winter, as well as deep seasonal freezing of soil have resulted in the formation of unsteady-state natural systems damageable under anthropogenic impact.

3. Conclusions
The geoecological assessment of zeolite-bearing rock mining and processing situation in the East Transbaikal area points at the necessity to undertake a system approach to zeolite production development in this region. The system approach should include integrated efficient use of the mineral, ecological properties of resource-saving technologies and minimization of anthropogenic load on the environment.

References
[1] Yusupov TS 1985 Methods of zeolite separation and concentration from rocks Identification of Zeolites and Their Content Testing in Rocks Novosibirsk: IGiG SO AN SSSR (in Russian)
[2] Pavlenko YuV 2000 Zeolite Deposits in East Transbaikal Chita: ChitGU (in Russian)
[3] Faleichik LM 2014 Geoinformation models for assessment of damage caused to nature by economic activities Vestnik ZabGU No 08 (111)