Introduction

Characteristics of the global production of rare metals in Russia

Basic hydro-mineral raw materials of the world

Characteristics of hydro-mineral resources of the Siberian platform

Aims and objectives of study

Characteristics of pit water as a hydro-mineral resource

Characteristics of brines of the Udachnaya explosion pipe

Problems and prospects of the production of hydro-mineral raw materials

Technologies of rare alkaline earth metal extraction from brines and pit water

Conclusions
„The basic principle of the ethical approach to the resource problem must be the responsibility to future generations...“

Robin Attfield
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Introduction

Today, one of the most important indicators of the economic development of a country is the level of rare metal production and consumption in various economic spheres. By the expression of the Academician A. E. Fersman, one of the founders of the Russian geochemistry, rare earth metals are “vitamins for industry” and important strategic potential.
Today, rare earth metals are critical raw materials in Russia. According to the data of the US Geological Survey, in 2009, Russia imported 49 000 t of rare earth elements, mainly cerium (38 500 t) and neodymium (5 900 t).

However, on the territory of Russia, there are large reserves of rare metals (almost 27 mln t $\sum$TR2O3).

In the world, Russia occupies the second place after China by this parameter.
Characteristics of the global production of rare metals in Russia

The resource potential of Russian deposits is much lower: the estimated resources of all categories do not exceed 27 mln t $\sum$TR2O3.

In the State Register of Reserves, 16 rare earth metal deposits are recorded.

The most explored are the Lovozero loparite deposit and apatite deposits of the Khibiny area (Murmansk region).

The Irkutsk region has significant reserves of rare metal ores, whose deposits compose the rare metal province of the East Sayan mainly located on the territory of the region. The local (partially explored) niobium, tantalum, lithium, beryllium, and cesium deposits are among the largest in the country.

According to the estimates of geologists, the province covers a large part of the country’s reserves: 65% of niobium, 45% of tantalum, and 50% of lithium.
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All the countries search for ways to urgently reduce rare metal deficiency in the global market. The main trends are as follows:

• Search for new suppliers and new deposits of rare metals

• Exploration of technogenic and secondary rare metal sources (landfills and tails of concentration factory, non-ferrous and rare metals ore processing products)

• Secondary processing of municipal waste containing rare metals (e.g., electrical and electronic equipment)

• Exploration of hydro-mineral resources and pit water as an innovative source of rare metals

Rare alkaline earth metals are strategic resources of many countries, including Russia.
Basic hydro-mineral raw materials of the world

**Natural waters**
- Groundwater
  - Hydrothermal vents of inter-continental rift zones
  - Hydrothermal vents of island arcs and Alpine fold areas
- Surface water
  - Brines of contemporary salt basins
  - Seawater
- Brines and water of artesian basins

**Pit water**
- Waste water and brines from petroleum production
- Waste water from thermal power plants of salt and potassium enterprises
- Waste water from desalination plants

Salton Sea
Searles Lake

Waste water and brines from petroleum production

Dr. Olga Ulanova
World Resources Forum, Davos, 14.October 2015,
Mining of rare earth metals from hydro mineral resources in Siberia: trends and prospects

East Siberian hydro-mineral province


Dr. Olga Ulanova
World Resources Forum, Davos, 14.October 2015,
An example of such a source is the East Siberian hydro-mineral province, which possesses unique reserves of lithium salt groundwater and brines.

The minimal commercial content of lithium in groundwater as an industrial raw material is 10-20 mg/dm³; the content of this component in the brines of the Siberian platform reaches up to 200-400 mg/dm³. Especially promising are the brines with the mineralization of up to 600 g/l (industrial water or hydro-mineral raw material).

The salt resources in industrial water (lithium, bromine, iodine, boron, cesium, rubidium, strontium, potassium, magnesium, and their compounds) at 55 promising locations are estimated at 84 mln. tons. At present, the evaluation of more than 30 industrial water deposits has been carried out.
From the point of view of industrial brines, in the Angara-Lena basin, the lower aquifer system is promising. Its brines are calcium chloride, sodium-calcium-chloride, and calcium-sodium-chloride with high concentrations of rare elements.

<table>
<thead>
<tr>
<th>Elements</th>
<th>Content, %</th>
<th>Content, g/dm³</th>
<th>Content, g/dm³</th>
<th>Content, g/dm³</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>from</td>
<td>to</td>
<td>average</td>
</tr>
<tr>
<td>Sr</td>
<td>100</td>
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<td>8,0</td>
<td>7,5×10⁻¹</td>
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<tr>
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<tr>
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</tr>
<tr>
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<td>3,0×10⁻¹</td>
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<tr>
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<td>9,0×10⁻⁵</td>
<td>6,0×10⁻⁵</td>
</tr>
<tr>
<td>U</td>
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<td>2×10⁻⁷</td>
<td>1,0×10⁻⁵</td>
<td>4,0×10⁻⁶</td>
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<tr>
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<td>3,0×10⁻²</td>
<td>1,3×10⁻³</td>
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<tr>
<td>V</td>
<td>2</td>
<td></td>
<td>5,0×10⁻⁵</td>
<td></td>
</tr>
<tr>
<td>Th</td>
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<td>3×10⁻⁷</td>
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<tr>
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<td>1,0×10⁻¹⁰</td>
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</tr>
</tbody>
</table>

Their composition is calcium chloride, sodium-calcium-chloride, and calcium-sodium-chloride with high concentrations of rare elements.
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Aims and objectives of study

The aim of the study is to evaluate the potential of hydro-mineral resources as innovative sources of rare earth elements in Siberia and to develop technological processes for selective extraction of rare alkali and alkaline earth metal metals from natural multicomponent brines.

To explore the issue, the Interagency Regional Educational, Scientific and Analytical Center on the Problems of Study and Rational Use of Hydro-mineral Resources of the East Siberia was founded on the basis of the Irkutsk National Research Technical University (INRTU) in 1998. Since then, research projects in the area have been carried out for more than 15 years.
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Pit water is often formed as a mixture of groundwater, precipitates, and process water used in the production process. Thus, it is necessary to distinguish between free and drainage water. This is a raw material globally used for the production of Br and I, calcium chloride, boron, bromine, and common salt.

Currently, it is not regarded as a separate group of industrial waters.

The amount of pit water reaches hundreds of millions of cubic meters per year, and the most of it is unused. The content of numerous microcomponents in them reaches significant concentrations. It is known that the strontium content in free water of the Kovykta gas condensate field is more than 300 mg/l; in brines of the Udachnaya explosion pipe, it is more than 1000 mg/l. Even at the minimum pumping capacity of 50 m3/hour, the throughput is about 130 t and 400 t per year, respectively, in terms of strontium.

Now, it is pumped back into the ground or poured on the surface. So, migrates into the soil and spreads throughout huge territories and, thus, it is lost irrevocably.
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Mining of rare earth metals from hydro mineral resources in Siberia: trends and prospects

The Udachnaya explosion pipe

Source http://nub1an.livejournal.com/
The Udachnaya explosion pipe is a diamond deposit in the north of Yakutiya. It is located 20 km from the Arctic Circle, in the Daldyn-Alakit kimberlite field. The pipe was discovered in June 1955 by V. N. Shchukin during the Amakinskaya geological expedition for deposit exploration.

Later, the Udachnyi settlement (now, the city) and an ore enrichment works (GOK) were constructed nearby for the industrial production of diamonds.
The Udachnaya explosion pipe

- Project pit depth is 640 m
- Surface area is 2000 x 1600 m, by the bottom 600 x 230 m
- Mine life (since 1971) is 45 years
- In 2014, the first starting complex of an underground mine was launched.
### The chemical composition of brines of the deposits within the “Udachnaya” explosion pipe

<table>
<thead>
<tr>
<th>Element</th>
<th>Concentration, mg/dm³</th>
<th>Industrial condition, mg/dm³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>minimum</td>
<td>maximum</td>
</tr>
<tr>
<td>K</td>
<td>210,00</td>
<td>37890,00</td>
</tr>
<tr>
<td>Na</td>
<td>10470,00</td>
<td>43033,00</td>
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<tr>
<td>Ca</td>
<td>591,00</td>
<td>80560,00</td>
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<tr>
<td>Mg</td>
<td>164,00</td>
<td>17290,00</td>
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<td>Li</td>
<td>7,00</td>
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<tr>
<td>Rb</td>
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<tr>
<td>Sr</td>
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<tr>
<td>Cu</td>
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<td>Mn</td>
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<td>3500,00</td>
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<tr>
<td>B</td>
<td>202,00</td>
<td>408,00</td>
</tr>
<tr>
<td>Br</td>
<td>1,20</td>
<td>5320,00</td>
</tr>
</tbody>
</table>

Quelle: [www://ru.wikipedia.org](http://www://ru.wikipedia.org)
The lithium content in a motherboard is 2x10^-4 to 2x10^-1 g/kg of PVC
(WEEE-Kategorien 3 und 4 (IT-Geräte & Geräte der Unterhaltungselektronik))

The lithium content in hydro-mineral resources is 2x10^-5 to 5x10^-1 g/kg of brine
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Problems and prospects of the production of hydro-mineral raw materials

- The issues of the complex exploration of groundwater brines, which are unique natural resources and sources of rare alkali earth metals, are not explored enough yet, despite the great prospects of this area.

- In a whole, the technology for industrial extraction of metals from brines is less developed than the studies of the raw material, which restrains its exploration. One of the main problems is the separation of rare and alkaline earth metals in the technological processes of their extraction. Thus, the quantities of components extracted from groundwater are low, and ones from free water are even lower.

- In Russia, only iodine or bromine are now extracted in the industrial scales, and the lithium extraction is planned.
However, the practice of mining enterprises, particularly, on the territory of the Siberian platform, is characterized by great amounts of pumped water, which is discharged into the environment and, thus, becomes liquid production waste due to the absence of the possibility of its use in the water cycle. The latter is related to its high mineralization. The water is most often discharged back into the ground or onto the surface.

Liquid wastes have much higher negative environmental impact than solid ones. It is caused by their high migration ability and, thus, larger areas affected.

**The impacts of the saline water discharge into aquifers:**
- geochemical anomalies;
- disturbed natural underground drain regime.

**The impacts of the discharge into surface waters:**
- increasing their surface water mineralization several times higher than maximum concentration limit;
- salination of surrounding areas and, thus, disturbed ecosystem balance.
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As a result of the performed studies, the ecological and economic feasibility was proved for the exploration of multicomponent brines of a number of the Siberian platform deposits with the purpose of deep and selective extraction of rare earth metals: lithium, rubidium, strontium, cesium, etc. from the sodium chloride brines of the Korshunovskii GOK (ore enrichment works) and from the calcium chloride brines of the Udachinskii GOK based on the following methods: the ion-exchange sorption, the eluent chromatography, the flotation, the crystallization, and the freezing. The technological schemes for metal extraction from free water and brines were developed.
The dependence of the degree of extraction of metal ions (Sr, Li, Rb, Ca, Mg, Na) on the hydrochloric acid concentration in the range of 0.1 to 8 N HCl was established. It was shown that the efficient separation and extraction of metals is reached by the gradient elution, which provides the products with the lowest content of impurities, particularly, 92% extraction of strontium and 97.9% extraction of rubidium.

Based on the height equivalent to a theoretical plate (HETP), the possibility of the chromatographic separation of Sr, Li, and Rb ions was shown using a KU-2x8 (Russia) and a Dawex-50x8 cation exchangers on brines at the 2 N HCL eluting.

A technological scheme of strontium and rubidium sorption from brines was proposed.
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Conclusions

- The issues of the integrated production of groundwater brines in Siberia are not explored enough yet, despite the great prospects of this area. However, it is apparent that the key technology in the deep processing of groundwater brines is the extraction of industrially valuable rare and alkaline earth elements.
- The brine mining does not require expensive and dangerous mining operations, which cover 80-85% in the production cost structure at the underground mining and 60-65% at the open-pit mining.
- The most of lithium, cesium, rubidium, iodine, and bromine is now produced from industrial water. Hence, Siberia can be a large supplier of rare alkaline earth elements, and Russia can cover the domestic needs and compete with the recognized leaders in the global market.
Thank you for your attention!