RED MUD: problem and solutions

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This presentation tries to answer some of the questions:

- How is red mud being recycled globally?
- What materials are produced?
- What are global prospects?
- What is done to use red mud in Nikolaev, Ukraine?
- What are the latest developments in the rare earths project in Jamaica?
- What is status of RUSAL project to extract Sc in Russia?
- What work is done by MISiS to create new technology to treat low iron containing materials?
Introduction
Status of Red Mud production and utilisation

RED MUD (Bauxite Residue):

- Global generation > 140 million tonnes/year;
- Global inventory > 3 billion tonnes;
- CAPEX and OPEX of disposal are typically below 4-8 $/t;
- Classified as less or non-hazardous tails for storage, i.e. no strong environment pressure;
- Global utilization ranges from 2 to 4 million tonnes/year, with no reliable data from China;
- Over 1200 patents to treat BR in the world with only few of the technologies implemented.

Source: CSIRO, 2009
## Status of Red Mud utilization

### Introduction

<table>
<thead>
<tr>
<th>Product from RM</th>
<th>Current utilization rate*, mtpa</th>
<th>Potential utilization rate*, mtpa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additive/ raw material to cement plants</td>
<td>1.0 – 1.5</td>
<td>100% red mud can be consumed. Today's annual global cement production has reached 2.8 billion tonnes, i.e. 140 Mt of BR a year is merely 5% of current annual cement production</td>
</tr>
<tr>
<td>Additive/raw material to iron and steel plants</td>
<td>0.2 – 1.2</td>
<td>100% red mud can be consumed. Today's annual global pig iron production has reached 1.1 billion tonnes, needing about 1.8 bt of iron ore with Fe 65%. Thus 100% red mud will be consumed to make 3% of total pig iron production.</td>
</tr>
<tr>
<td>Direct iron reduction technologies</td>
<td>-</td>
<td>Potentially attractive after mastering of technologies</td>
</tr>
<tr>
<td>Sc and REE extraction</td>
<td>-</td>
<td>Promising. Pilot plant trials are in progress</td>
</tr>
<tr>
<td>Building materials (bricks)</td>
<td>0.5 – 1.0</td>
<td>Use the sand separated from red mud (China)</td>
</tr>
<tr>
<td>Sorbent, coagulant, fertilizer, pigment, catalyst, ceramics, environm. appl.</td>
<td>0.3</td>
<td>Relatively small utilization volume, depending on local conditions</td>
</tr>
<tr>
<td>Total</td>
<td>2.0 – 4.0</td>
<td></td>
</tr>
</tbody>
</table>

* Source: UC RUSAL assessment
Nikolaev Alumina Refinery
BR as iron additive in cement production

- Simple preparation at disposal site by passing mud slurry via system of ponds and channels followed by excavating and drying;
- Low cost of processing, no capex;
- Up to 250,000 tpa of RM shipped to 10 cement plants in Ukraine, Russia, Moldova, Belorussia for distance up to 950 km;
- Used as iron and aluminium source for raw material feed for cement plants;
- On-site mixing of the RM is undertaken to ensure consistent Fe and Al levels to meet customers’ needs;
- Made possible due to warm climate and coarse particle size of RM, not applicable to refineries in Russia.

<table>
<thead>
<tr>
<th>Component</th>
<th>Min</th>
<th>Max</th>
<th>Typical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al₂O₃</td>
<td>6</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>34</td>
<td>64</td>
<td>47</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.5</td>
<td>7.5</td>
<td>3.3</td>
</tr>
<tr>
<td>Moisture</td>
<td>7</td>
<td>20</td>
<td>12</td>
</tr>
</tbody>
</table>
Extraction of Scandium and Rare Earths Elements

- Extraction of Sc and Rare Earths allows to increase economic efficiency of the overall process;
- Red muds in Russia, Jamaica and China are characterized by extremely high content of REE – more than in any other ore (90 – 150 ppm Sc, 300-350 ppm Y and La, upto 600 ppm Ce);
- RM is fully prepared for processing and contains much less radio nuclides and more useful elements compared to conventional processes for REE (extraction of Sc from Uranium production as practiced in USSR);
- Various processes are under development to extract from 15 to 75% of Sc from RM with producing \( \text{Sc}_2\text{O}_3 \) with 99% purity;
- Scandium, making alloy with Al with extraordinary properties for mainstream applications in the aerospace and automotive sectors, has more market value compared with all other REE in RM.
Jamaica Project of JBI - NLM

RM as source of REE

- Pilot project of Nippon Light Metals (NLM), realized at site of Jamaica Bauxite Institute (JBI) commissioned in Oct. 2013, but concluded in Oct. 2014;
- 30 t of RUSAL Windalco RM used;
- Dysprosium (Dy) and Nyodymium (Nd) (used in the manufacture of lasers and magnets) were main targets (to remove monopoly of supply from China);
- The foreseen industrial production – 1,500 tonnes of REE per year;
- Main influencing factors behind project put on hold:
  - fall in price of REE (WTO's removal of restrictions of Chinese exports);
  - high production costs to extract small amount of Dy and Nd;
  - use of sulfuric acid process – need to treat acidic cake and effluents.

Contenent of REE in red mud (UC RUSAL), ppm:

<table>
<thead>
<tr>
<th>Red Mud</th>
<th>Sc</th>
<th>Dy</th>
<th>Nd</th>
<th>Pr</th>
<th>Total REE*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windalco</td>
<td>140</td>
<td>55</td>
<td>250</td>
<td>30</td>
<td>2400</td>
</tr>
<tr>
<td>Kamensk</td>
<td>100</td>
<td>30</td>
<td>200</td>
<td>50</td>
<td>1600</td>
</tr>
<tr>
<td>Aughinish Nikolaev</td>
<td>50</td>
<td>20</td>
<td>70</td>
<td>15</td>
<td>800</td>
</tr>
</tbody>
</table>

* Excluding Sc
UC RUSAL Sc extraction project

RM as source of Sc

- Pilot plant for scandium concentrate production commissioned in 2014;
- Proprietary “carbonation” technology is used with no acidic effluents to the main Bayer process;
- Improving technical parameters of scandium concentrate production in pilot scale – end 2015;
- Development of technology to produce scandium oxide (99.0 %):
  - in lab scale - 4 quarter 2014,
  - in pilot scale - 4 quarter 2015.
- Technology to produce $\text{Sc}_2\text{O}_3$ with higher purity (99.98 %) can be developed if supported by market requests;
- Feasibility study for industrial production – 4 quarter 2015;
- Potential tonnage of RM utilization – 2 000 000 tonnes, which can yield 50 000 kg $\text{Sc}_2\text{O}_3$ per year.
Extraction of Iron from RM
Using red mud as blast furnace feed or in new type furnaces

- **UC RUSAL** developed additives on the basis of RM to be used in blast furnace:
  - Flux for agglomerate – industrial trials showed sinter strength increase by 4.1%, reduction of sintering fuel consumption by 11.8%;
  - Binder for bentonite substitution – pilot industrial trials show increase of iron ore pellets strength by 15%.
- Requires **additional investment** at iron and steelmakers facility, that hinders application of RM as an additive;
- Similarly, volume of RM used as Blast Furnace feed in **China** is highly influenced by **iron ore market prices**, currently is limited;
- Moscow Institute of Steel and Alloys (MISiS) develops **new generation furnace** to process red mud and produce pig iron and slag products, with reduced energy consumption and improved metal quality compared to established Romelt technology;
- Similar trials are done in Greece (pilot plant producing iron and mineral wool).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Romelt</td>
</tr>
<tr>
<td>Area of furnace, m²</td>
<td>20</td>
</tr>
<tr>
<td>Specific productivity, t/m²h</td>
<td>1.0</td>
</tr>
<tr>
<td>BR consumption, kg/t pig iron</td>
<td>3,185</td>
</tr>
<tr>
<td>Coal consumption, kg/t pig iron</td>
<td>1,264</td>
</tr>
<tr>
<td>O₂(95%) consumption, nm³/ t pig iron</td>
<td>1,027</td>
</tr>
</tbody>
</table>
Further Development Directions

View of UC RUSAL

• Develop highly profitable, low volume applications (like Sc extraction) to support use in less attractive bulk applications of remaining RM material;

• Reduce costs and increase volume of current RM use in Iron & Steel and Cement industries, arrange tax and other support from state;

• Develop pig iron production technologies with lower capex, reduced specific energy consumption, allowing for production of marketable products (besides blast furnace feed) – building pilot unit;

• UC RUSAL is doing significant efforts in this direction.

Way forward: individual projects or collaborative efforts?
Thank you for your attention!

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