Exploration, mining and metals production & Boliden Kokkola

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Kokkola Material Week
30.10.2018
Boliden in a nutshell

- A world-class mining and smelting company
- Sweden, Finland, Norway, Ireland
- 6 mining areas, 5 smelters
- Number of personnel 5 500, of which in Finland 1 500
- Turnover 4,2 mrd €
- The discover of the large gold finding in Boliden, Sweden 1924, laid the foundation of the company
Our business model – part of a circular economy

Exploration → Mining → Concentration → Raw materials → Metal production → Sales

Metal grade:
- Zn: 3–7%
- Cu: 0.2–1.6%

Metal grade:
- Zn: 55%
- Cu: 25%

Metal grade:
- Zn: 55%
- Cu: 25%

Metal grade:
- Zn: 99.995%
- Cu: 99.9975%

Collection and recycling of metals

The use of metals in society

External concentrate suppliers

Industrial production

6 mining areas

5 smelters
Products

Base metals
- Zinc
- Copper
- Lead
- Nickel
- Cobalt

Precious metals
- Gold
- Silver
- Pt, Pd

Concentrates and other products
- Metal concentrate
- Sulphuric acid
- By-products (Se, Te..)
# Metal production

<table>
<thead>
<tr>
<th>Production, Mines</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc, ktonnes</td>
<td>305</td>
</tr>
<tr>
<td>Copper, ktonnes</td>
<td>143</td>
</tr>
<tr>
<td>Nickel, ktonnes</td>
<td>14</td>
</tr>
<tr>
<td>Lead, ktonnes</td>
<td>60</td>
</tr>
<tr>
<td>Gold, kg</td>
<td>7,237</td>
</tr>
<tr>
<td>Silver, kg</td>
<td>413,238</td>
</tr>
<tr>
<td>Tellurium, kg</td>
<td>34,979</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Production, Smelters</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc, ktonnes</td>
<td>457</td>
</tr>
<tr>
<td>Copper, ktonnes</td>
<td>353</td>
</tr>
<tr>
<td>Nickel in matte, ktonnes</td>
<td>25</td>
</tr>
<tr>
<td>Lead and lead alloys, ktonnes</td>
<td>78</td>
</tr>
<tr>
<td>Gold, kg</td>
<td>17,776</td>
</tr>
<tr>
<td>Silver, kg</td>
<td>569,474</td>
</tr>
<tr>
<td>Sulphuric acid, ktonnes</td>
<td>1,613</td>
</tr>
</tbody>
</table>
Exploration at Boliden

- Identify new minable deposits
- Prolonging production life of mines
- Exploration close to our mines is prioritised
- Upgrade deposits from resources to reserves

Successful exploration in Garpenberg yields long lifespan. The mineral reserve increased by 36 Mtonnes.
Our mines

- **Aitik**
  - One of the most productive open-pit copper mines in the world
  - Copper, gold and silver

- **Boliden Area**
  - Three underground mines and one open-pit mine
  - Zinc, copper, lead, gold, silver and tellurium

- **Garpenberg**
  - One of the most productive underground zinc mines in the world
  - Zinc, silver, lead, copper and gold

- **Kevitsa**
  - Open-pit mine acquired in 2016
  - Nickel, copper, gold, platinum, palladium and cobalt

- **Kylylahti**
  - Underground mine acquired in 2014
  - Copper, gold, zinc, nickel and cobalt

- **Tara**
  - Europe’s largest zinc mine
  - Zinc and lead
Business Area Mines

- Six mining units in Sweden, Finland and Ireland
- World class productivity levels at several mines
- Value creation through prolonging life of mines
- High-level technical expertise
- Operating profit: SEK 6,681 m
- Number of employees: 3,164

Breakdown of revenues by metal:

- Zinc, 31% (32)
- Copper, 35% (28)
- Nickel, 4% (4)
- Lead, 6% (6)
- Gold, 12% (13)
- Silver, 9% (15)
- Other, 3% (2)
Our Smelters

Bergsöe
- One of Europe’s biggest recycling facilities for lead batteries and the only secondary lead smelter in the Nordic region
- Lead and lead alloys

Harjavalta
- Investing in enhancing nickel processes and modernising copper production
- Copper, nickel matte, gold, silver and sulphuric acid

Kokkola
- One of the world’s biggest zinc smelters
- Zinc and zinc alloys, sulphuric acid and silver in concentrate

Odda
- A significant exporter to Europe’s steel industry
- Production capacity increased to 200 ktonnes of zinc per year
- Pure zinc, zinc alloys and sulphuric acid

Rönnskär
- One of the world’s leaders in recycling of electronics
- Copper, gold, silver, lead, sulphuric acid, zinc clinker, etc
How Boliden’s smelters work

Recycled secondary materials
Metal concentrates from mines

Cu Copper
Ni Nickel
Zn Zinc
Pb Lead

Products
Underground storage

Rönnskär Harjavalta
Kokkola Odda
Bergsöe Rönnskär

Group Presentation 2018
Boliden Kokkola – Since 1969

Zinc production capacity 315 000 tonnes / year.
Celebration!!!

After 49 years of operation on Thursday 23rd August 2018

**10 Million tonnes** of zinc cathodes produced was reached at Boliden Kokkola.
Conventional zinc production RLE - process plus direct leaching

Video: https://www.boliden.com/fi/operations/smelters/boliden-kokkola#

RLE = Roasting, leaching, and electrowinning.

Two leaching lines: 1. Roasting and Calcine Leaching.
2. Atmospheric Direct Leaching (DL) of Concentrates.

- Jarosite precipitation in the DL reactors.
- Jarosite and elemental sulphur is mixed as combined residue in the DL reactors.
Great example of the importance of long term industrial symbiosis with respect of Circular Economy

https://www.youtube.com/watch?v=ti9TBDN51e4
Circular economy – Industry point of view

- Circular economy should be seen and understood in a broader perspective.
- The efficient use of side streams may result difficult concentrated streams
  - In addition to extracting valuable elements a safe home must be provided for the unwanted extra elements.
  - Safe use of safe final disposal. For example: As, Cd, Sb, Cr, Hg, etc..
  - Limited safe uses should be allowed.
- The trend has been supporting better yields but at the same time tightening regulations are banning uses for individual elements.
- Also the moving targets in impurity element levels creates insecurity in developing processes.
  - Sometimes composition level is declared as the most important, sometime bioaccumulation or solubility…
  - Some degree of predictability in legislation is needed.
- All elements can be separated form each other but it requires infinite amount of energy and money.
  - Matter does not disappear…
Ore bodies are getting more complex and include more unwanted impurities

- The demand of metals will increase.
- Recycling will be more important part of the metals circulation but it will not replace the need of primary production.

Need for
- Cost effective innovations and technologies.
- Improved energy efficiency.
- Full benefit from the side streams and minimization of the amount of generated wastes.
- Outlet and safe disposal or usage for the unwanted impurities (As, Cd, Hg, Ca, Fe, S, F, ...).
By-product metal relations to Zn, Cu and Ni

- Mineralogy important in both primary and secondary materials.
- Energy, work and money needed to separate elements from each other.
Typical critical- and other elements found in zinc refining
Zinc process produce iron residue that is currently landfilled

- Precipitation of iron removes harmful impurities (As, Sb, Al, Ge, Pb, F, Hg…) from the process and is part of solution purification prior electrolytic recovery of 99.995 % pure zinc metal.

- Fe ~15 wt-%, Zn 2-3 wt-%, Pb 3 wt-% Ag, In, Ga, Ge in ppm levels.

- Direct Leaching makes jarosite and sulphur residue that is currently landfilled as combined waste (Jarosite + sulphur).

- **Landfilled amount 6 Mt** since 1969.

- Boliden Kokkola has invested in double filtration process. Mechanical stability improves and less volume.
Boliden Kokkola pond area sections

Major landfilled streams are jarosite and sulphur residues
- Classified as hazardous waste
- Annual amount of jarosite 130 000 ton
- Annual amount of sulphur residue 100 000 ton
Added value from high Mn-containing anode sludge

- MnO2/Mn2O3 precipitates in zinc electolysis process from the solution at lead/silver anode.
- This anode sludge contains impurities such as metallic lead from the anodes.
- Pyro- and hydrometallurgical purification methods have been investigated for several applications.

**Annual amount of high Mn containing anode sludge is 3000-4000 tonnes**

**Thermal processing**

MnO2 / alloys for steelmaking

**Selective leaching**

Mn, Zn concentrate for fertilizer use

**Selective leaching and purification**

High purity MnSO4 salt
Purification of manganese (Mn) containing anode sludge

- Possible product in steel industry, as fertilizer or high purity MnSO4 precursor for lithium-ion batteries.

Collaboration with Kokkola University Center Chydenius
Ongoing investigations for waste treatment options

Sulphur residue waste valorization

- Boliden Kokkola produces 100 000 dry tonnes of sulphur residue annually. Sulphur content is circa 70 wt-% and the rest is metal mixture Zn, Ag, Fe, Cu, Ni,...

- The amount of sulphur residue in separate historical pond is 830 000 wet tonnes (330 000 dry tonnes).

- Pre-treatment of the wet residue and thermal processing was successfully studied in several piloting campaigns.

- Products after roasting piloting resulted suitable SO2 gas for sulphuric acid production

- In addition valuable metals containing calcine (Zn, Ag, Cu, Pb) is obtained for further recovery.
Concluding thoughts

- Processing of non-ferrous residues and side streams are increasingly studied.
- This trend is driven by tightening legislation in many places.
- Combined hydro- and pyrometallurgical processes required.

Possibilities

- Possibility to recover more metals.
- Obtained end products like slag can be used in construction.

Challenges

- Energy demand increases as well CO2 emissions. Non-fossil carbon sources?
- Safe and legal outlet needed for elements of concern As, Cd, Hg...
- How clean the slag has to be in different applications?

Cement out of slag
Overcoming challenges in the circular economy!

- Possibilities to obtain sustainable economical solutions
- Something must come out of the loop and hazardous substance must be dealt with.
- Education, training, new concepts need to be developed to meet new legislation and purity demands of products.

SOCRATES Policy brief
European Training Network for the sustainable, zero-waste valorisation of critical-metal-containing industrial process residues

Overcoming challenges in the circular economy: A thermodynamic reality-check

http://etn-socrates.eu/
Martin wants to get the job done. He couldn’t without metals.

Means of communication are essential for growing communities. They bring people and jobs closer together and make it possible for people to move forward in life. Trains, buses and tablets all depend on copper and zinc, that are used in everything from electrical wires to steel bodies. Martin is ready to do his best, and so are our metals.
Aitik

- One of the world’s most productive open-pit copper mine
- Copper, gold and silver
- Large volumes and rational methods gives high productivity
- Milled tonnage: 39 Mtonnes
- Operating profit: SEK 2,073 m
Boliden Area

- Three underground mines and one open-pit mine
- Mineral-rich mines on historic ground
- Zinc, copper, lead, gold, silver and tellurium
- Milled tonnage: 2,065 ktonnes
- Operating profit: SEK 868 m
Garpenberg

- One of the world’s most productive underground zinc mines
- One of the world’s most modern mines
- Zinc, silver, lead, copper and gold
- Milled tonnage: 2,634 ktonnes
- Operating profit: SEK 2,606 m
Kevitsa

- Open-pit mine in one of Finland’s biggest deposit areas
- Opened in 2012, was acquired in 2016 and is still ramping-up
- Nickel, copper, gold, platinum, palladium and cobalt
- Milled tonnage: 7,911 Mtonnes
- Operating profit: SEK 893 m
Kylylahti

- Underground mine in Finland
- A geological interesting area
- Copper, gold, zinc, nickel and cobalt
- Milled tonnage: 809 ktonnes
- Operating profit: SEK 34 m
Tara

- Europe’s largest zinc mine
- Zinc, lead and silver
- Exploration success in 2016
- Milled tonnage: 2,311 ktonnes
- Operating profit: SEK 942 m
Bergsöe

- One of Europe’s biggest recycling facilities for lead batteries
- The only secondary lead smelter in the Nordic region
- Lead and lead alloys
- Customers: European battery industry
- Production – lead alloys: 50 ktonnes
- Operating profit: SEK 110 m
Harjavalta

- Copper, nickel matte, gold, silver and sulphuric acid
- Investing in enhancing nickel processes and modernising copper production
- New sulphuric acid plant in 2019
- Customers: construction, electronics, electrical engineering and automotive industries
- Production – copper: 133 ktonnes
- Production – nickel in matte: 25 ktonnes
- Operating profit: SEK 707 m

Harjavalta’s nickel matte station
Kokkola

- One of the world’s largest zinc smelters, second largest in Europe
- World class in terms of emissions and energy efficiency
- Zinc and zinc alloys, sulphuric acid and silver in concentrate
- Operating profit: SEK 688 m
Odda

- A significant exporter to Europe’s steel industry
- Production capacity increased to 200 ktonnes of zinc per year
- Pure zinc, zinc alloys and sulphuric acid
- Operating profit: SEK 225 m
Rönnskär

- One of the world’s largest electronic recycling units
- Copper, gold, silver, lead, sulphuric acid and zinc clinker
- Production – copper: 219 ktonnes
- Operating profit: SEK 900 m