TRENDS AND TREATMENT OF IMPURITIES IN COPPER MINING

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Topics

1. GLOBAL TRENDS
2. ECOMETALES
3. FINAL REMARKS

EcoMetales: Environmental solutions for the mining industry
An unresolved problem

Structural problem: Most new copper deposits have a high arsenic content.

Closed circuit: The process of scorodite, or similar, stable residue is not applied extensively.

Stricter environmental norms for transporting and processing complex concentrates are expected.

EcoMetales: Environmental solutions for the mining industry
Arsenic content concentrate output is growing fast:

0.13% in 2000 ...>0.20% in 2016...0.30% in 2020, according to ICSG

Chile is the world’s leading producer of copper in concentrates with 24% of total

14% Peru
10% China
5% Australia
4% USA

Chile should increase its share to 26% by 2030.

Perú
- El Brocal (Buenaventura): 5 - 8% As
- Cobriza (Doe Run): 0.4 - 0.6% As
- Chinalco: 0.5 -1% As
- Magistral (Nexa Resources) (*): 1% As
- Cañariaco (Candente Resources): 1% As
- Other projects: La Granja, Galeno

Chile
- DMH (Codelco): 1 - 3% As
- Chuqui (Codelco): 0.5 - 2% As
- El Teniente (Codelco): 0.15 - 0.20% As
- Collahuasi: paying penalties on higher As

(*) Projects;

Sources: Codelco, Cochilco, Anglo American, EcoMetales, ICSG

EcoMetales: Environmental solutions for the mining industry
20% of Chile’s copper is exported to Japan today, compared to 30% in 2008

Japan is Chile’s second most important destination for copper concentrates after China which represents 41% of the total

- The volume of Cu concentrates with high As will increase in the international market
- Blending practice is an option but not a suitable solution
- Chemical or biological treatment is needed, either using a hydrometallurgical or pyrometallurgical route

Source: Chilean Copper Commission, 2018.
Some copper concentrates can be harmful to the marine environment and a risk to crews.

China set a benchmark maximum of 0.5% As in concentrates; other countries have reduced the limits further.

On the first day of 2018, China ban scraps imports.

The EU-28 established best available techniques (BAT) in 2016 for waste reduction of copper and other metal industries, including the reduction of quantities of waste sent for disposal from copper production.

Sources: ICSG, Cochilco.
Environmental issues & community concerns: 
a Chilean case

Citizens' perception of the most severe environmental challenges

- Air pollution
- Urban waste
- Noise
- Pollution in general
- Vehicles (noise, pollution, etc.)
- Chimneys and firewood use
- Water pollution or scarcity
- Release of pollutants from trees
- Lack of green areas
- Street dogs
- Odours
- Climate

None/other/don't know

Pese a que primer día de alerta sanitaria redujo en 20% el nivel de SO₂, restricción en 8 industrias no logra frenar las intoxicaciones: el Hospital de Quintero tuvo que atender a 86 personas

ENAP REFINERÍA ESTIMA EN US$ 200 MILLONES SU INVERSIÓN PARA CUMPLIR CON EL FUTURO PLAN DE DESCONTAMINACIÓN:

El fantasma de las paralizaciones en Quintero obliga a calcular costos y tomar resguardos extras a las empresas de la zona

En la industria asumen que la autoridad será cada vez más exigente, y aunque en el Ministerio del Medio Ambiente aseguran que no habrá paralizaciones constantes, los privados ya hacen cálculos de eventuales detenciones. Un buque petrolero parado en el marr cuenta entre US$ 25 mil y US$ 35 mil diarios y la menor producción de energía puede significar pérdidas de más US$ 100 mil cada día. • CLAUDIA RAMÍREZ

SOURCES: El Mercurio newspaper, OECD, Ministry of Environment - Chile
Chile’s air quality and emission standards for copper smelters

- **Environmental regulation in Chile** (since 1990) has a shorter history than Japan and US (early 1970s)

- **Chilean smelters are now working to reach a new SO$_2$ and As emission standard by 2018**, which will:
  
  **A**
  
  Reduce emission limits by 225% for As and by 186% for SO$_2$

  **B**
  
  Increase SO$_2$ and arsenic capture to 95% for current operations and to over 98% for new smelters. Average capture today is about 85%

- **A new stricter air quality standard** for SO$_2$ is being analyzed for a 2020 startup

- Chile is working hard to reduce emissions but needs to close the gap with international **standards** such as those in Japan, EU or China

Details on standards in Annex I

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**EcoMetales**: Environmental solutions for the mining industry
Chilean regulations for waste treatment and disposal of impurities

D.S. Nº 148/2003: Management of Hazardous Waste:

• **Scope**: Generation, storage, transport, treatment, reuse & recycling, disposal

• **Focus on** characterization and toxicity (TCLP test), but not on Best Available Techniques

Extended producer responsibility (EPR) (mining waste not included)

Some figures in copper smelters (7 operations)

• +110 kt/y of flue dusts (1-15% As) and 4,000 m³/y of acid effluents (acid plants)

• 85% of total flue dust with As is treated at EcoMetales plant and As disposed as scorodite together with Sb and other impurities

• Almost all the As from acid effluent is treated with lime, while one operation uses NaSH

In summary, regulatory trends will place greater requirements/obligations on the treatment and disposal of unstable waste containing impurities in Chile

Details per operation in **Annex II**
Copper smelters and other metallurgical plants in Chile face the following challenges:

- Improve environmental performance
- Reduce costs and to increase productivity
- Introduce more automation and technological improvements
- Energy recovery
- Recovery of strategic metals (Bi, Ge, Sb, etc.) and alternative uses for waste like slag or sulfur.

**EcoMetales**: Environmental solutions for the mining industry
EcoMetales: Environmental solutions for the mining industry
About EcoMetales Limited

(ECL)

ECL is a 100% subsidiary of CODELCO, established to implement environmental solutions and metal recovery processes in the mining industry.

Our facilities are strategically located 35 kms northeast of Calama. ECL has a total workforce of about 300 and more than 250 environmental permits for the transportation, treatment and disposal of hazardous waste.

ECL currently processes waste from CODELCO and is looking for opportunities to work with other mining companies.

EcoMetales: Environmental solutions for the mining industry.
EcoMetales’s development plan

- PLCC (Autoclave Technology)
- As–Sb Stabilization (AAA)
- Copper Recovery
- Recovery of Cu, H₂O, H₂SO₄
- Copper
- Other Materials

Growth with new customers. Commercial Know-how

To meet the Codelco needs with new processes.

Ej. Division El Teniente project, Tailings, by-products

MINING WASTE & VALUE RECOVERY

EcoMetales: Environmental solutions for the mining industry
## Projects & business

<table>
<thead>
<tr>
<th>CURRENT PLANT</th>
<th>WASTE VALORIZATION</th>
<th>PLCC PLANT</th>
<th>DET PLANT</th>
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</thead>
<tbody>
<tr>
<td>Flue dust leaching &amp; As disposal as Scorodite</td>
<td>Leached residue: Recovery of Ag, Cu and Ge. A new hydro process in evaluation Tailings: Recovery of minor elements. Tailings characterization and lab testing.</td>
<td>Feasibility engineering completed in 2017 Environmental permit approved in 2017 Independent Review Approval and decision to go forward in 2018</td>
<td>Environmental permit approved in 2018 Definition of El Teniente Division for project continuity in 2018</td>
</tr>
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</table>

### 2018

- **Productivity Improvement 2018/2017:** + 47% Production and – 22% cost
- **Declassification Scorodite 2018:** It will allow its disposal under less demanding conditions

### 2019/2020

- **Scorodite 2.0:** Volume reduction and encapsulation (2019)
- **AAA process commercialization:** B.O.T. contract – Technical license (2019)
- **Replacement of calcium arsenite by scorodite**
- **Geo-polymer study for existing calcium arsenite deposits**
- **End of the transfer area**

- **Leached residue:** First Milestone Cu recovery (2019) Second Milestone recovery of other elements (2020).
- **Tailings:** Technical-economic process evaluation (2019).

- **PLCC PLANT**
  - Pressure Leaching of Complex Concentrates

- **DET PLANT**
  - Improvement of arsenical waste generation, transport and disposal at El Teniente Division, Codelco

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**EcoMetales**: Environmental solutions for the mining industry
Arsenic stabilization process
(Chilean Patent Grant 50423)

ECOMETALES LANDMARKS:
We had a problem...

Continuous learning during the plant operation

2006
Precipitation of scorodite at laboratory scale.

2010-2012
- PAA Project
- Pilot Plant Trials
- PAA Construction
- PAA Start-up

2013
Start of operation of PAA

2014
- Improvement of boiler use and limestone preparation stage.

2015
- Optimization of ferric solution preparation stage

2016
- Improvement of oxidation stage

2017
- Optimization of precipitation stage

2018
- Improvement of automatic control

EcoMetales: Environmental solutions for the mining industry
Since 2007, EcoMetales has processed about 470,000 tonnes of flue dust and 782,000 m$^3$ of acid effluent, recovering about 90,000 tonnes of copper. More than 12,000 tonnes of arsenic have been disposed as scorodite since 2013.
EcoMetales plant:
Arsenic stabilization process

EcoMetales: Environmental solutions for the mining industry
Complex concentrate leaching project (PLCC)

The process involves the leaching of complex copper concentrates through a high-pressure vessel. The arsenic stabilization is also performed inside the vessel.

The project capacity is 200,000 t/y, the go-ahead decision should be taken during 2018.

Advantages:

- Almost zero emission
- Stable waste as scorodite
- Utilization of existing SX-EW facilities
- Low water consumption
- Competitive costs

Environmental permit approved in 2017

The schedule defines the start-up for the new facilities in 2020-21

Capex USD $ 324 million

EcoMetales: Environmental solutions for the mining industry
El Teniente Project
Arsenic removal from sulfuric acid plant effluents (weak acid)

The project will produce arsenic trisulfide instead of the current process based on treating arsenic with lime.

**Advantages:**

- 5 times less waste volume
- less than 1 ppm of [As] in treated effluent
- 500,000 m³ landfill facility inside El Teniente facilities, avoiding current transportation through populated areas outside Codelco’s division

**Environmental permit was approved in 2018**

**Capex USD $ 70 million**

**EcoMetales:** Environmental solutions for the mining industry
Other developments & cooperation opportunities

- Recovery of trace elements (Ag, Bi, Sb and Ge) from smelter flue dusts (in cooperation with K-UTECH Salt Technologies and RMC with CORFO – Eureka support)
- Tailings processing & recovery of value metals (in cooperation with JRI Ingeniería Chile, CORFO project)
- Oxidation of As (III) and Fe (II) using new biotechnological methods (in cooperation with CeBiB – University of Chile)
- Increase of current copper recovery of flue dust treatment plant (ECL)
- Treatment of Acid Mine Drainage (AMD)

EcoMetales: Environmental solutions for the mining industry
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EcoMetales: Environmental solutions for the mining industry
The treatment of arsenic remains an unsolved problem worldwide with several pending challenges in the mining sector:

Transportation of higher As content and more complex concentrates

Stricter regulations for air emissions and waste disposal

Communities deeply concerned about environmental pollution issues

Metallurgical facilities’ management of flue dust and acid effluent still needs to improve treatment and disposal of arsenic and other impurities. More research is needed for the removal of As from water sources, as well as for more efficient disposal alternatives.

EcoMetales supports JOGMEC’s initiative related to the separation of impurities from copper raw materials at the mineral processing stage.

From a more integral perspective, it is also necessary to find the best solution for the residual fraction of high arsenic concentrate.

EcoMetales is looking for synergies and collaboration to solve the challenge posed by arsenic treatment and disposal.

EcoMetales: Environmental solutions for the mining industry
Thanks you!!!
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