



Universidade de Brasília

CENTRO DE INVESTIGACION MINERA Y
METALURGICA



Case Study of LCIA in Chile

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Mining industry is one of the most important economical and social sector in South America.

- The world's largest copper producer is Chile (34% of the total world production*), and also has the biggest known reserves of copper. Chile produces also Au, Ag, Mo, Li, others metals.
- Brazil has the largest iron production (22% of world production **), and is also a leading supplier of niobium, tantalite; Brazil produces gold, bauxite, kaolin, tin, copper, others.

* *Report on Copper Market of the Chilean Copper Commission. October 2006.*

** *The Iron Ore Market 2006-2008, Unctad . May 2007.*

Comparative study of the environmental impacts of the copper smelting plants of Chile and Brazil.

“South American Project of Life Cycle Assessment of Metals, for Sustainable Mining Production” (Acronyms: **PROSUL**)*

To establish main characteristics of a LCA modelling for primary metal production in South America: identifying, through a gate to gate comparative study, main generic and local aspects.

Copper primary production was chosen, because:

- Comparable smelting plants in Chile and Brazil
- Copper is an important commodity for both countries
- Copper plant are well settled through the Chilean territory
- There is a huge amount of process information, and databases

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- *Chilean Research Center for Mining and Metallurgy, CIMM*

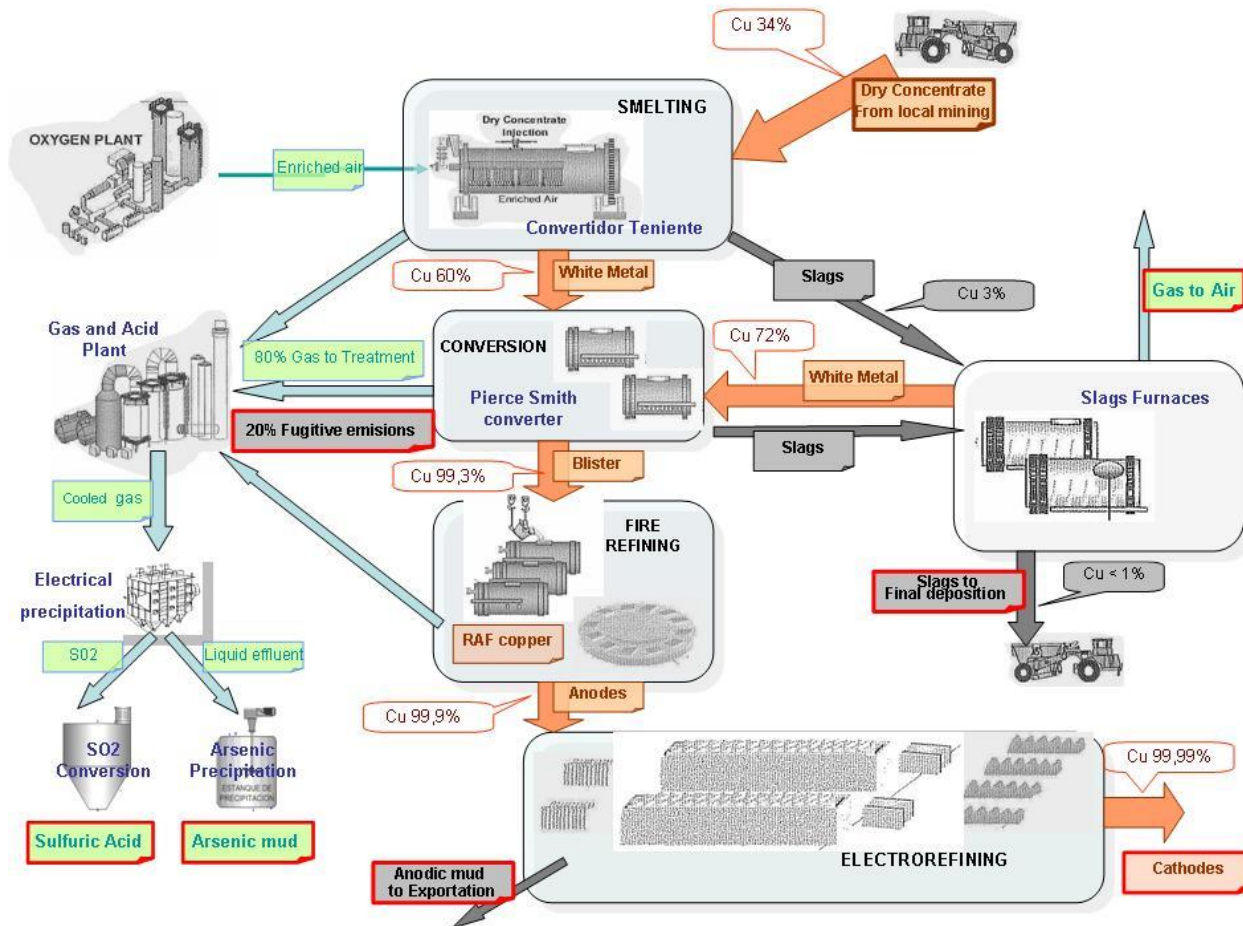
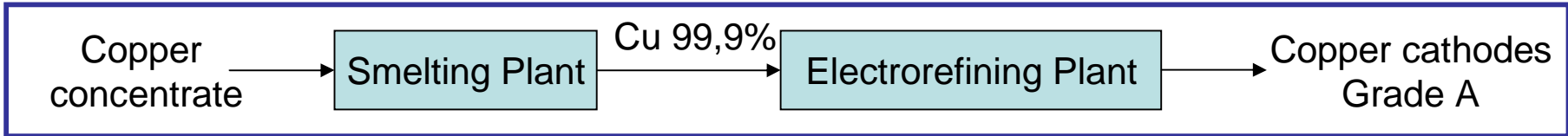
System Definition:

- Smelting plant of copper concentrates
- Electro-refining plant
- Acid Plant and Arsenic Plant

Exclusions (not comparable):

- Ore extraction process and the mineral resource area
- Mineral processing phase (comminution, concentration plant)
*Caletones Plant of Chile processes mineral only from local origin, and
Caraíba Metais of Brazil processes a mixture of concentrates of local and
imported origins*
- Transportation is also excluded from the defined system.

Both Brazilian and Chilean copper production, include standard pyrometallurgical processes which start with the entry of copper concentrate to the smelting plant, and end with the production of copper cathodes (99,99% Cu) in the electro-refining plant. **Functional unity: 1.000 ton of copper produced.**



LCI: data were compiled both from secondary and primary sources, such as articles, thesis, governmental agencies and technical information taken from the metallurgical plants, mass and energy balances. Some data were also taken from SimaPro and Gabi databases, when there was a lack of information.

	Caletones/Chile (t/1,000 t Cu)	Caraíba/Brasil (t/1,000 t Cu)
Inputs		
Cu (conc)	3,170.73	2,903.22
Lime (20%)	113.17	100.00
Iron sulfate	3.32	30.00
Coque	9.76	20.00
SiO ₂	417.07	0
Barium sulphate	0	2.50
NaOH (50%)	0	2.10
Limestone (Calcium Carbonate)	12,98	1.10
Sodium carbonate	5,75	0
Water	4,417.00	15,330.00
Natural Gas (m3)	40,345.59	29.1
Enap-6 (full oil)	30.75	0
Liquefied Natural Gas	3,634.15	0
Diesel (L)	10,831.59	1.90
Electrical energy (MWh)	1,041.46	1,550.52

	Caletones/Chile (t/1,000 t Cu)	Caraíba/Brasil (t/1,000 t Cu)
Outputs		
Products and Subproduct		
Total refined copper	1,000.00	1,000.00
Sulphuric Acid (98%)	2,121.95	1,950.00
Granulated copper slag	1,300.00	1,540.00
Sulfuric Acid (105%) (Oleum)	0	277.50
SO ₃ liquid	0	46.50
Arsenic mud	58.30	1.56
Anodic mud	15.5	2.60
Atmospheric emissions		
SO ₂	512.00	93.31
As	1.30	0.10
Liquid effluents		
Liquid effluents	0	5,100.00

20% of gases generated in Caletones goes to the air.

Brazilian smelting plant declares a lower percentage of gas emissions (only 5%).

Fugitive gases contain sulfur dioxide and arsenic.

The Metallurgical Plants Chosen and their Surrounding Environments

Chilean Smelting Plant

The Smelting Plant of Caletones of the El Teniente Division of Codelco, produces annually 418,000 MT of refined copper, and is located in Central Chile, 150 Km from Santiago and 20 Km far from the city of Rancagua.

Caletones is 1,500 meters high in the Mountain of Los Andes, in a zone with deep valleys and steep gorges, described as a Mediterranean and semi-arid region.

The El Teniente Division complex has produced copper for around 85 years.

Codelco: National Copper Corporation

Brazilian Smelting Plant

Caraíba Metais S.A. started its copper production operation in 1982. The company is principally engaged in the manufacture of copper cathodes in Brazil, producing 219,700 MT of refined copper.

It is located in Dias D'ávila, State of Bahia, and is part of the Camaçari Petrochemical Complex, the largest integrated industrial complex in Latin America, 41 Km from Salvador.

The Smelting Plant is 10 Km far from populated cities (55,600 inhabitants) and surrounded by a green environment containing native species.

The LCIA Study:

- Review of the LCIA Models available in literature,
- Review of models available in Sima Pro
- Information on population density and ecosystems, from the National Environmental Agencies, academic studies and risk assessment projects
- There were not enough information in any of the two countries, to evaluate land use and eutrofication impacts.

Impact Categories:

- Human health
- Acidification of soils
- Ecotoxicity
- Global impacts (CO₂, O₃ depletion, Fossil Fuels)

LCIA was based on SimaPro, using Eco-indicator 95 and 99, depending of the impact categories.

- Eco-indicator 95 (SimaPro), for all the specific potential impacts.
- Eco-Indicator 99: carcinogens and respiratory inorganics (both expressed in DALY^[1]). Carcinogens and respiratory inorganic impacts, were corrected taken into account the corresponding population density in each specific area of copper production.
So, the first step was the direct application of these models, but considering population density variations in South America:
correcting factors for population density (respect to the Europe population average, 160 P/km²) were used to calculate damage.

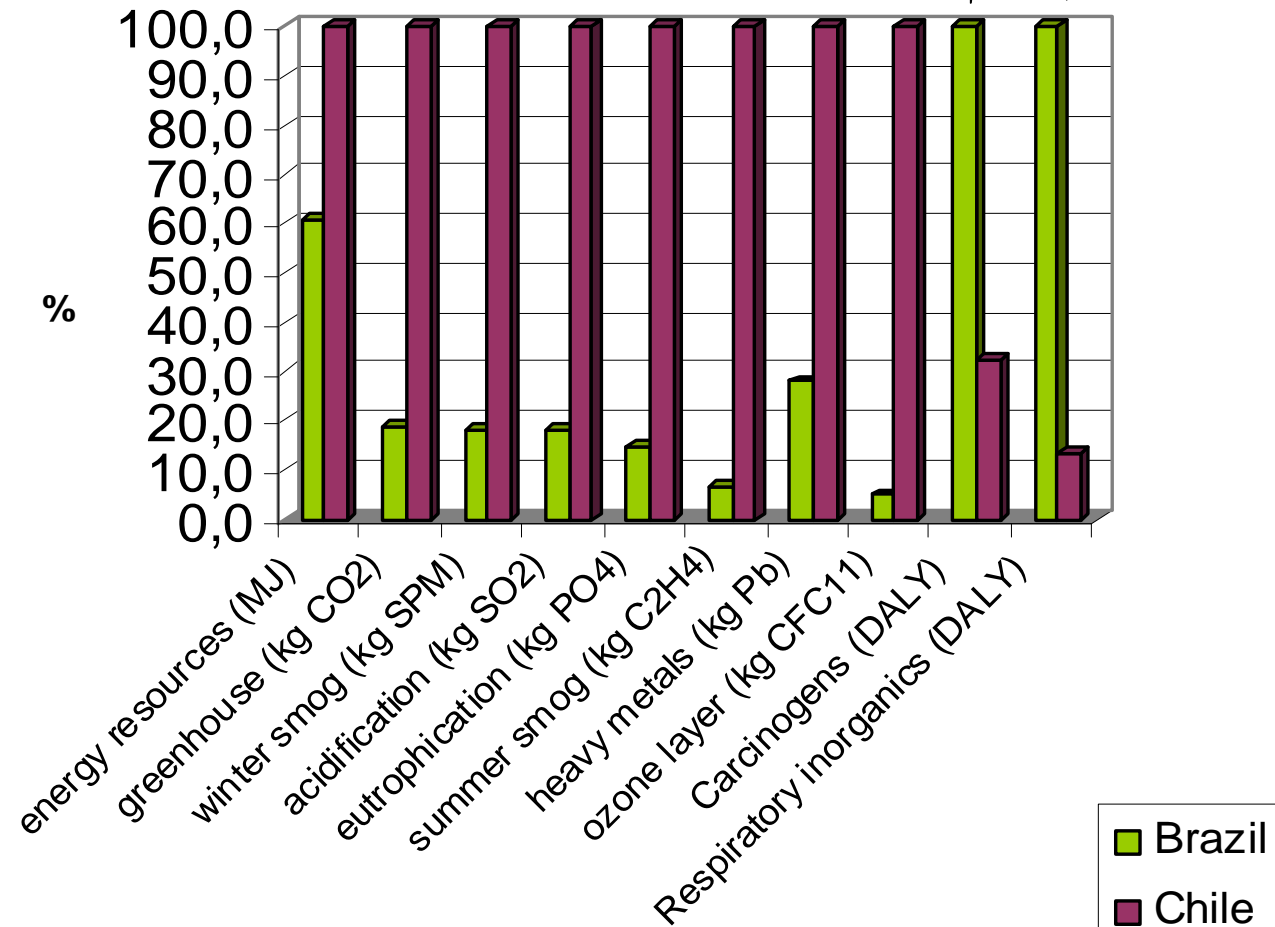
Brazil: population density in Dias D'Ávila county, is similar to Europe average.

Chile: in the area of Caletones , the population density is 4 P/km², it is 40 times lower than the European average

^[1] DALY = *Disability Adjusted Life Years*

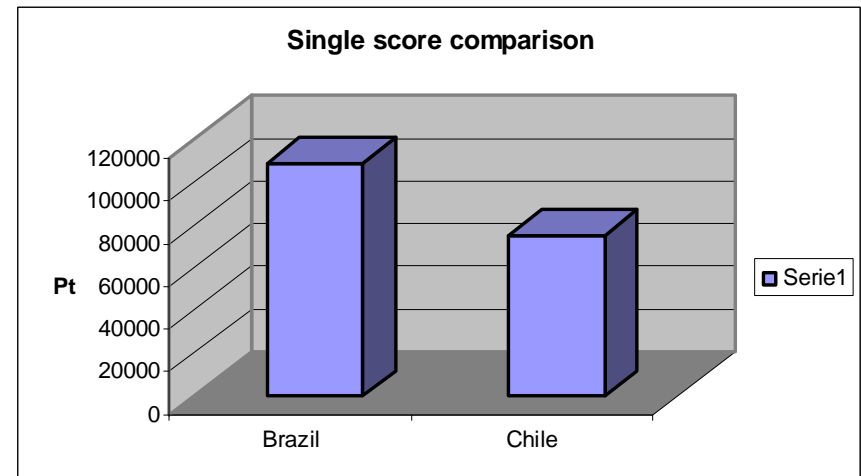
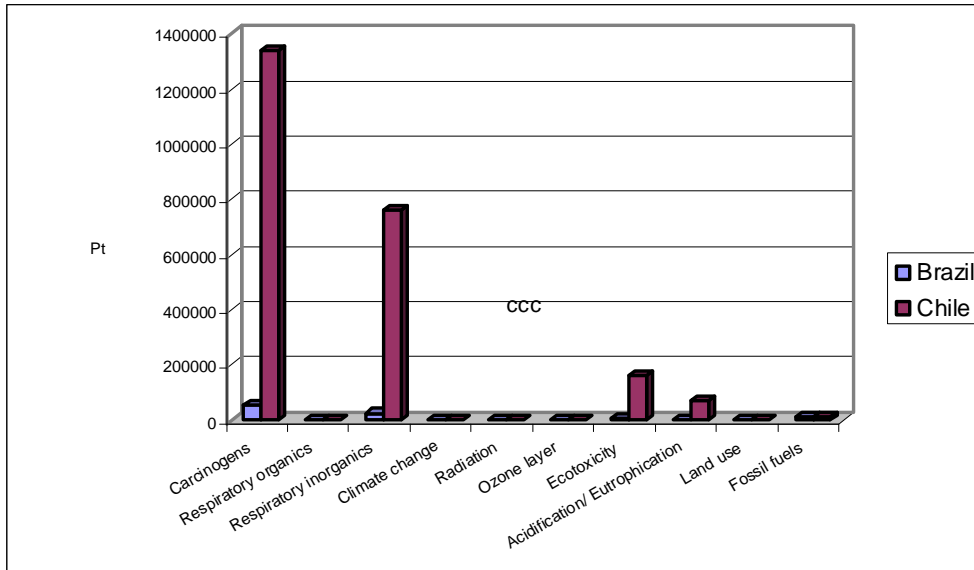
Relative Comparison of Brazilian and Chilean Cases

Results from EI 99 corrected

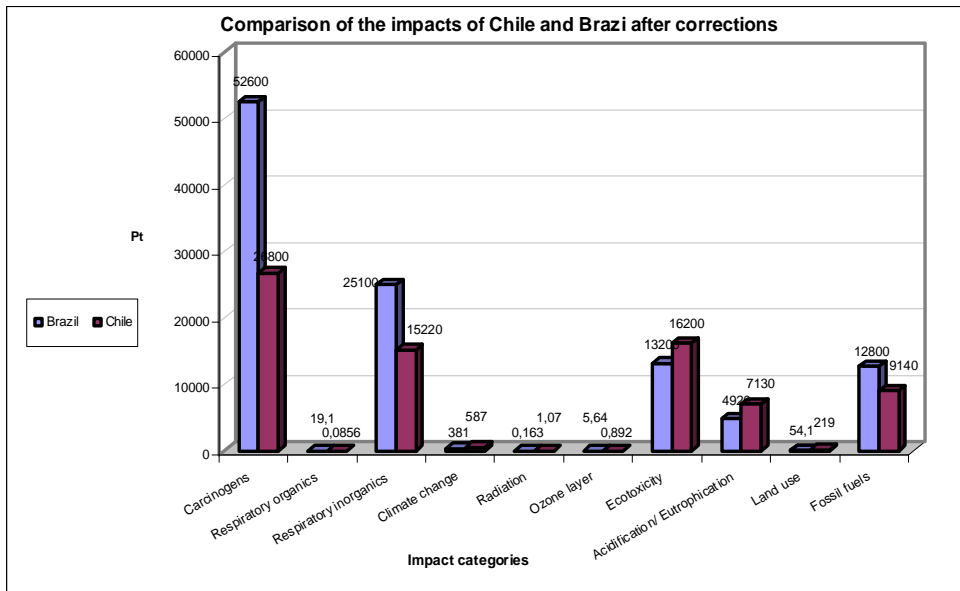


RESULTS

Comparison of Impacts before correction



Comparison of the impacts of Chile and Brazi after corrections



RESULTS

1. Accordingly to the LCI, the inputs related to energy resource, such as natural gas, diesel, are larger in Chile. Caraíba Metais takes all its power from an external network which is mainly hydropower. Consequently, environmental effects due to combustion processes result larger for the Chilean production (like summer smog).
2. Caletones's plant capture 80% of its exhausting gases from the smelting process, as these gases contain higher levels of arsenic, this plant present bigger characterization factors for impacts such as winter smog, acidification and heavy metals.
3. The results regarding carcinogens and respiratory inorganics impacts indicate that health effects of the Brazilian process are larger
4. The acidification effects on the soil and ecosystem are very evident, (visually) in the Chilean production area (not the case in Brazil). This is probably due to the technological characteristics of the plants, the late incorporation of the acid plant (gases treatment) to the Chilean process and the very long period of production of Caletones. Chilean authorities declared this area "saturated zone" (120,000 ha around the smelter).

Conclusion

Specific research is needed to characterize mining sector and the site specific conditions of each region, under which the mining activities take place.

LCIA results obtained in this study allow us to determine that the main specific and sound information required to understand the environmental and health implications of the mining production systems, is :

- Characterization of the population density distribution to evaluate Health Impacts.
- The history of the incorporation of technology improvements and of the production system itself, to better evaluate impacts such as soil acidification, ecosystem damages, health impacts.
- Characterization of the specific ecosystems (risk assessment studies of native species: exposure, effects and tolerance to mining emissions).
- Native species density and distribution, in the affected area.
- Real damage done (level of acidification of soils, determination of damage to biota, damage to the technosystem).
- Dispersion models for PM10 and PM2,5 particles in the production area.
- Definition of a base line (what happens with the impacts associated to other human and industrial activities in the Region or associated to natural phenomena, and before operations).
- Land use studies

Final Conclusions and Recommendations:

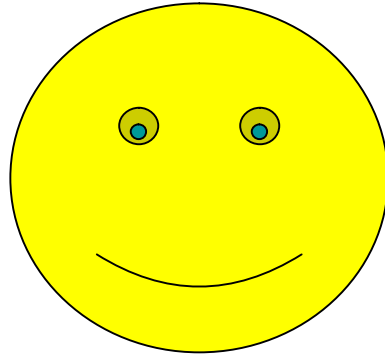
- Hydropower is a better environmental option.
- Acid plant is an environmental benefit, if comparing with sulfuric acid production from sulfur minerals (this is good thing of the copper smelting plants). And the sulfuric acid produced in the pyrometallurgical process of copper is completely consumed in the hydrometallurgy of the copper oxide minerals.
- This comparative study of the Chilean and Brazilian primary copper production done under the framework of the Prosul Project, was a great step for South American LCA studies. It is the first LCA study developed for the mining sector involving more than one Latin American country, and contributed to identify potential environmental and health impacts of mining production. It has also a significant learning value.

Future studies must comprises:

LCIA: Development of site specific models for South America and for mining sector

LCI: Development of QA/QC guidelines for data gathering and building of datasets of mining production .

Conduct monitoring campaigns to fill important lack of data information of the metallurgical production system.



Thank you for your attention! .