INTMET
Clustering Conference
“Fostering Innovation in the Iberian Pyrite Belt“

INTEGRATED INNOVATIVE METALLURGICAL SYSTEM TO BENEFIT EFFICIENTLY POLYMETALLIC, COMPLEX AND LOW GRADE ORES AND CONCENTRATES

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No: 689515

INTRODUCTION

- Currently there is **no economical and viable process** for on-site metal extraction from Low Grade, Complex or Poly-metallic deposits (mainly Cu, Pb & Zn).

- Traditionally, metals recovery from polymetallic sulfide deposits is performed by mining, **selective flotation** to separate Cu, Pb and Zn concentrates, and finally, smelting/refining of those concentrates to obtain the refined metals.

- In many cases, selective flotation of that kind of complex ores produces **low metals recovery and low concentrate quality** containing impurities such as Hg, As, Bi, etc., which results on high penalties in treatment and refining charges, and consequently, worsening the economy of the mining business.

- Recovery of the valuable metals could then be maximised by producing bulk concentrates or middling flotation products to feed **novel hydrometallurgical processes**, proposed by INTMET project applying on site mine to metal concept.

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THE OBJECTIVES

- **Integrated** sustainable metallurgical system: hydro-, bio-, electro-chemistry (Mine to Metal)
- Maximising **metal recovery** yield (Cu, Zn, Pb, Ag & CRM)
- Minimising **energy** consumption
- Minimising **environmental** footprint
- Ensuring the **economic** viability of the entire process
- **Upstream** (pre-processing) and **down-stream** (treatment/use of metallurgical wastes such as slags, dusts, effluents) interfaces should also be considered.

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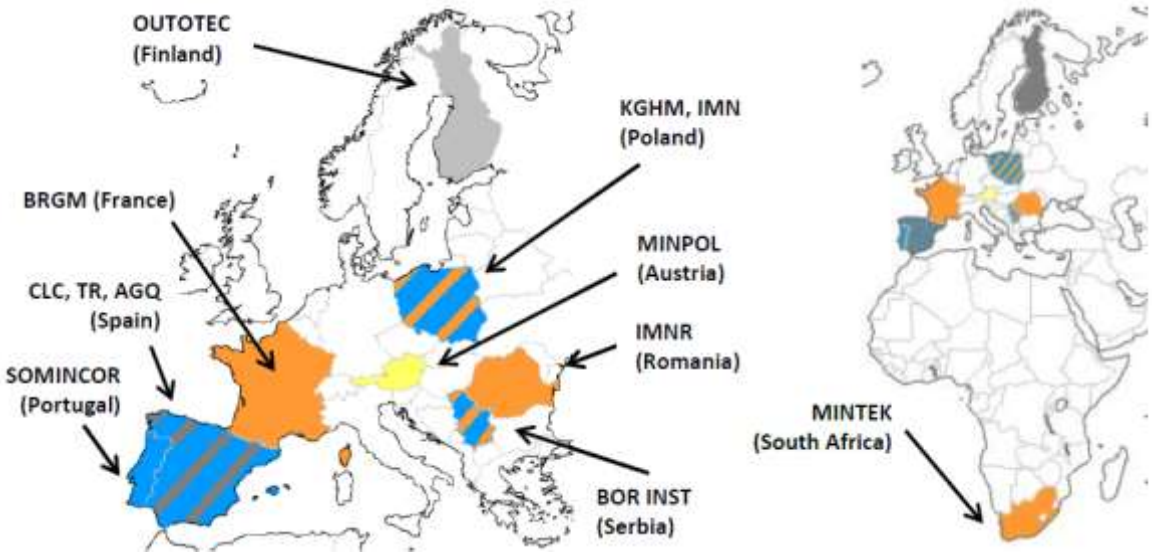
PARTICIPANTS

The project is being developed by a distributed consortium with 12 partners from 9 different states (Spain, Portugal, Poland, France, Finland, Netherland, Austria, Serbia and South Africa).



3 Mines: Cobre Las Cruces – KGHM – SOMINCOR

2 Technology Providers: OUTOTEC – Técnicas Reunidas

2 SMES: MINPOL – AGQ Mining

5 Research Centers: IMN – MINTEK – IMNR -- BRGM – BOR INST

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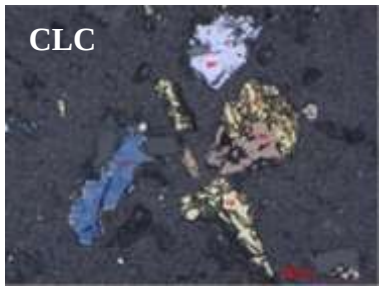
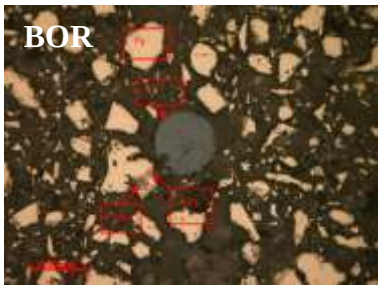
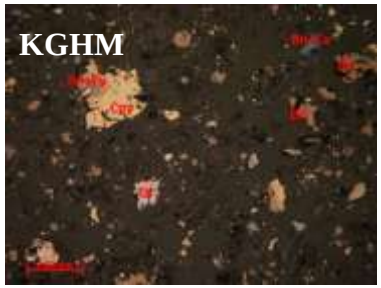
RAW MATERIALS

Four different bulk concentrate materials, from mine partners, were submitted for laboratory bench-scale tests applying different technologies. Samples used for the study were characterised showing the following composition:

Sample	Cu (%)	Zn (%)	Fe(%)	Pb(%)	Ag (ppm)
CLC	1.4	5.4	35.3	3.3	82
BOR	1.8	4.9	23.8	4.6	120
SOMINCOR	4.8	9.5	28.9	13.1	265
KGHM	12.8	1.1	8.2	4.7	663







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ENHANCED PERFORMANCE FLOTATION PROCESS

This activity developed the necessary technology for **bulk concentrate production**. Main areas of activity were comminution and flotation improvements and production of samples from the developed processes.
Newly developed **flotation reagents** and **microwave** techniques have been applied. **Electrical pulse fragmentation** has been tested as a pre-concentration technique. Additionally, pilot plants have been established to confirm results producing samples for further testing activities.


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ATMOSPHERIC LEACHING

The proposed leaching process takes place in reactors containing a **ferric sulphate** medium at atmospheric pressure, **with oxygen injected and sulphuric acid** added to maintain optimum reaction conditions. The principal reactions that take place in the process for primary metal sulphides are:

$$CuFeS_2 + 2Fe_2(SO_4)_3 = CuSO_4 + 5FeSO_4 + 2S$$

$$ZnS + Fe_2(SO_4)_3 = ZnSO_4 + 2FeSO_4 + S$$

$$PbS + Fe_2(SO_4)_3 = PbSO_4(s) + 2FeSO_4 + S$$

$$FeSO_4 + H_2SO_4 + {}^1/_2\,O_2 = Fe_2(SO_4)_3 + H_2O$$

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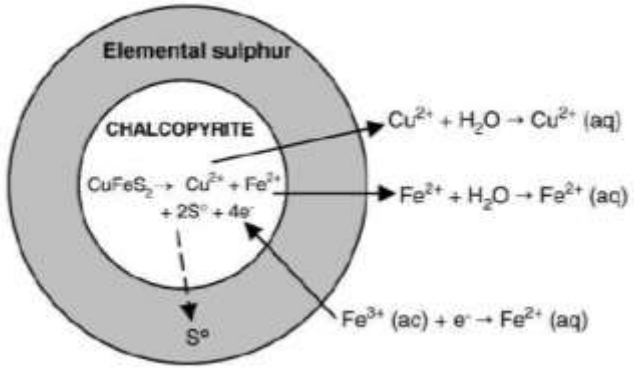
ATMOSPHERIC LEACHING

Chalcopyrite ferric leaching process is impaired due to the sulphur layer produced in the course of the leaching reaction, and copper leaching efficiencies are low normally. To overcome this effect, the use of silver as a catalyst substantially improves the progress of the reaction.

The effect of silver is mainly obtained due to the following reactions:



$$CuFeS_2 + 2\ Ag_2SO_4 = CuSO_4 + FeSO_4 + 2\ Ag_2S$$

$$Ag_2S + Fe_2(SO_4)_3 = 2AgSO_4 + 2\ FeSO_4 + S$$

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PRESSURE LEACHING

High temperature pressure oxidation is a well proven process for Ni, Au and Zn production; in addition to that currently different semi-commercial plants are developing an alternative process for Cu. In this process, the extreme conditions of **pressure oxidation** in an autoclave at a **temperature from 135°C up to 210°C** that destroy sulphides rapidly (leach time as low as 60 min) releasing base metals into solution for further recovery.

INTMET project propose the use of this technology as an efficient way to recover base metals from bulk concentrates and middlings obtained from complex ores.

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PRESSURE LEACHING

The pressure leaching laboratory tests were performed in an autoclave with internal volume of 3.8 L. The autoclave included heating jacket, cooling coils, baffles, temperature measurement and control, pressure measurement and control, gas feed valves and controller, sampling valve and magnetically driven agitator with upper and lower impellers.

The oxidative pressure leaching tests were carried out over the temperature range of 180 – 210 °C

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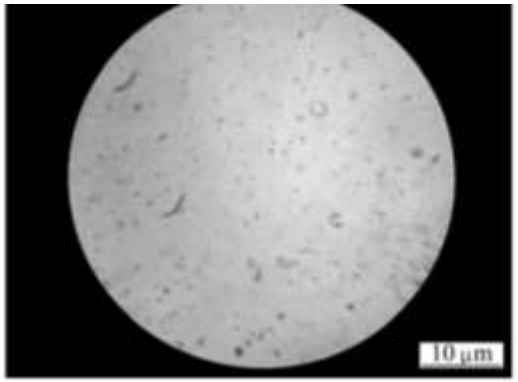
BIOLEACHING

Treatment of complex polymetallic concentrates is a niche application for bioleaching processes. Issues which could have important implications for metals extraction performance and process costs include:

- ❑ Presence of significant levels of **inhibitors** such as Hg and Ag
- ❑ **Incomplete Cu extraction** where Cu occurs predominantly as chalcopyrite.

Solutions to overcome the slow and incomplete extraction of copper from chalcopyrite include operating the process at high temperatures using **thermophiles**



2 Optical micrograph of mixed mesophilic culture

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BIOLEACHING

The laboratory bioleaching test work was carried out at **45 and 70°C** using **moderately thermophilic and thermophilic** cultures on laboratory-scale, using continuously operated and mechanically agitated reactors comprising 4 stages (6 L total).

The reactors were supplied with CO_2-enriched air. The reactors were monitored continuously for temperature, pH level, redox potential and O_2 and CO_2 consumption rates.

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TESTING RESULTS

Atmospheric Leaching Results

CLC SAMPLE		
ATM Leaching	Cu Ext. (%)	Zn Ext. (%)
No catalyst	65.7	72.1
With catalyst	97.5	94.5

BOR SAMPLE		
ATM Leaching	Cu Ext. (%)	Zn Ext. (%)
No catalyst	69.2	19.6
With catalyst	88.9	73.2

SOMINCOR SAMPLE		
ATM Leaching	Cu Ext. (%)	Zn Ext. (%)
No catalyst	63.4	75.2
With catalyst	87.8	95.5

KGHM SAMPLE		
ATM Leaching	Cu Ext. (%)	Zn Ext. (%)
No catalyst	98.1	97.2

Atmospheric leaching of **CLC** sample with catalyst is very promising due to the **high copper and zinc recoveries**. In the case of **KGHM** sample, **no catalyst** addition was necessary due to the high natural silver content in the raw material (as shown in slide 5). The results obtained on the **other samples** showed that even with catalyst addition only moderately good extractions were achieved, making this kind of sample **more complex than anticipated**.

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TESTING RESULTS

Atmospheric Leaching Results

Based on these results, an atmospheric leaching pilot plant with capacity of 300 kg/h bulk concentrate was designed, installed and operated continuously at the Las Cruces mine, using CLC fresh concentrate as feed material. After hot commissioning, ramp up, and nominal condition operation the results with silver catalyst addition emulated that obtained during the laboratory tests, with Cu and Zn dissolutions of up to 94 and 95% respectively


Pilot Plant


Flotation


Leaching

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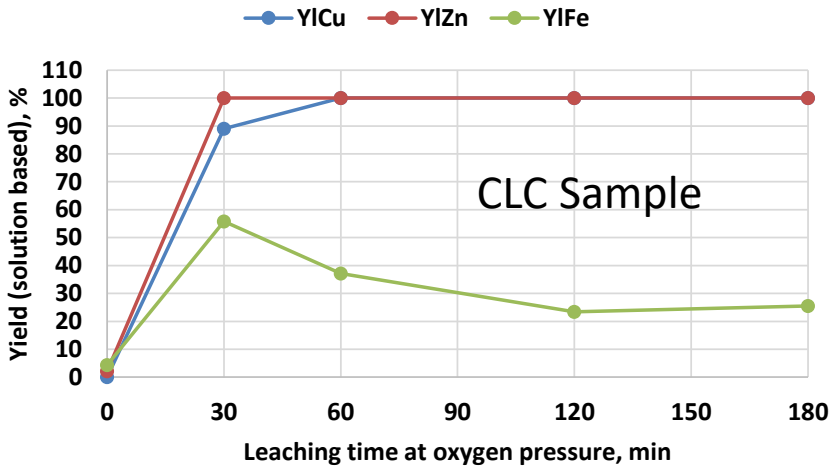
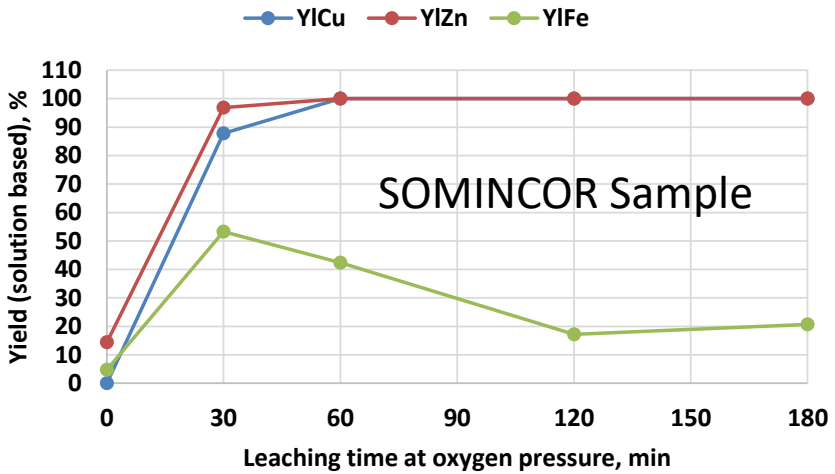
TESTING RESULTS

Pressure Leaching Results





Both concentrate samples showed good Cu and Zn leaching characteristics. Close to 100% extraction was achieved over the temperature range investigated.

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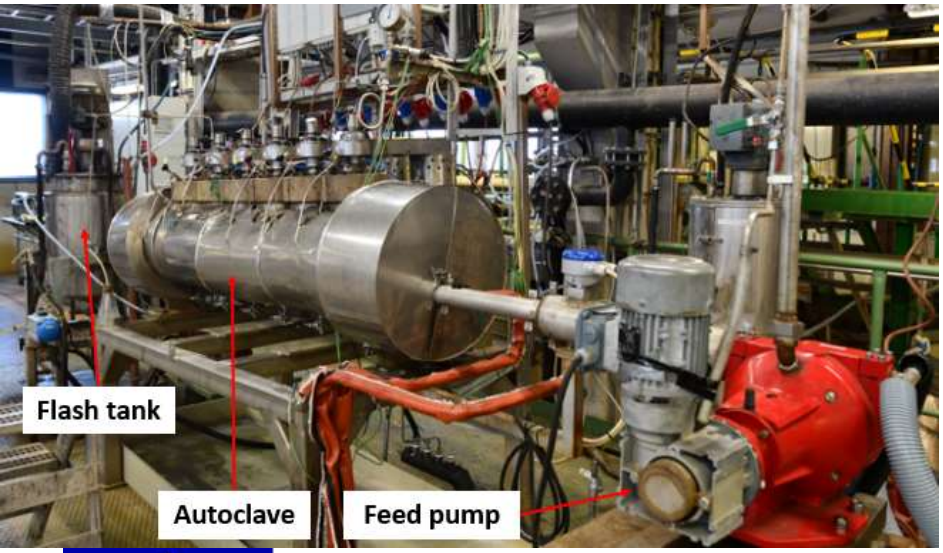
TESTING RESULTS

Pressure Leaching Results

Based on lab results, a pressure leaching pilot plant with an autoclave capacity of 60 liters was designed, installed and operated continuously at Outotec facilities, using SOMINCOR sample as feed material. After hot commissioning, ramp up, and nominal condition operation the results confirmed the laboratory tests results, with the following efficiencies: 95% Cu, 99% Zn & 90% Pb



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TESTING RESULTS

Bioleaching Results

SAMPLE CLC		
Bioleaching	Cu Ext. (%)	Zn Ext. (%)
45ºC	54	82
70ºC	89	96

SAMPLE BOR		
Bioleaching	Cu Ext. (%)	Zn Ext. (%)
45ºC	85	65
70ºC	91	70

SAMPLE SOMINCOR		
Bioleaching	Cu Ext. (%)	Zn Ext. (%)
45ºC	44	93
70ºC	>92	99

SAMPLE KGHM		
Bioleaching	Cu Ext. (%)	Zn Ext. (%)
45ºC	>94	88
70ºC	>94	95

Results indicated that thermophilic bioleach conditions would be required to achieve acceptable Cu and Zn recoveries on samples 1, 2 & 3, whereas high Cu extractions could be achieved on the KGHM sample at moderate temperatures. The data obtained from the bench-scale studies showed that bioleaching would be a feasible option for treatment of these materials (treatment on BOR sample to be optimized for zinc recovery).

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TEST RESULTS

Bioleaching Results

Pilot facilities have been designed and arranged to demonstrate the bioleaching process on BOR concentrate according to lab scale obtained results. Efficiencies up to 87% Cu, 75% Zn, 90% Pb & 80% Ag have been obtained after piloting.

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TEST RESULTS

Treatment/use of metallurgical wastes such as slags, dusts, effluents

Produced polymetallic concentrate from tailings fulfilled quality requirements and may be used in further hydro-processing.

Different methodologies has been tested for the Pyrite oxidation, sulphur valorisation and iron recovery.

Different types of wash sulfuric acids from technological gases purification in copper and zinc industry (Sulphuric Acid Plants) were used for gypsum production.

Different types of effluents from Cu extraction and processing have been tested to purify effluents i.e. fractional precipitation, adsorption and chelating treatment process and ion exchange.


Pyrite Oxidation


Effluent Cu recovery

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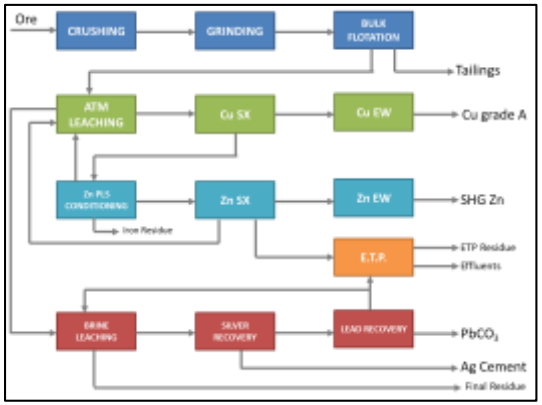
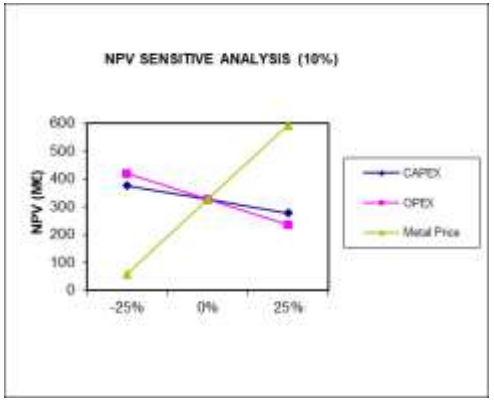
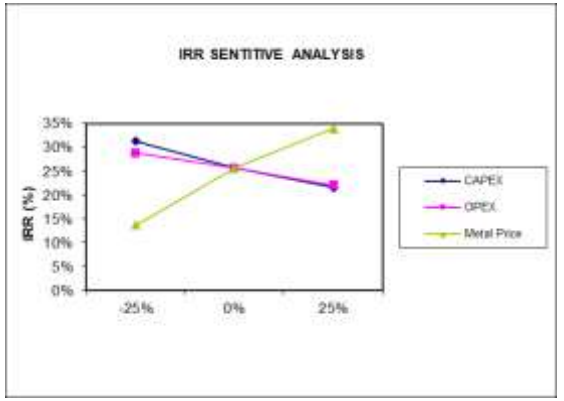
TECHNOLOGIES ASSESSMENT

Final economic and environmental assessment have been performed for several case studies based on mines located in Europe, providing in general rather positive economic results:

Hydrometallurgical plant treating from **0.6 to 1.0 million tpa** of bulk concentrate to produce **15-25,000 t/y Cu** metal, **40-60,000 t/y Zn** metal, **30-80,000 t/y Pb** metal and **50-100** t/y Ag. Internal rate of return, **IRR, varies from 14 to 27%,** depending on metal production value. Net present value, **NPV, ranges 125 to $325 million**, depending on specific conditions.







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CONCLUSIONS

Encouraging results have been obtained with the use of the different technologies proposed by INTMET project.

Atmospheric leaching using catalyst has been demonstrated for efficient treatment of polymetallic, complex and low grade ores. **Metals recoveries around 95%.**

Pressure leaching showed near to 100% leaching efficiencies for copper and zinc at laboratory scale an around **95% and 99%** respectively at pilot scale.

Bioleaching shows promising results on the tested samples with **85% Cu, 75% Zn, 90% Pb, 90% Au and 80% Ag**.

Technologies assessment showed **promising results to apply INTMET** process technologies for low grade, polymetallic and complex ores.

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