Effect of nutrient and raffinate addition in bioleaching of a pyrrhotite-pyrite ore

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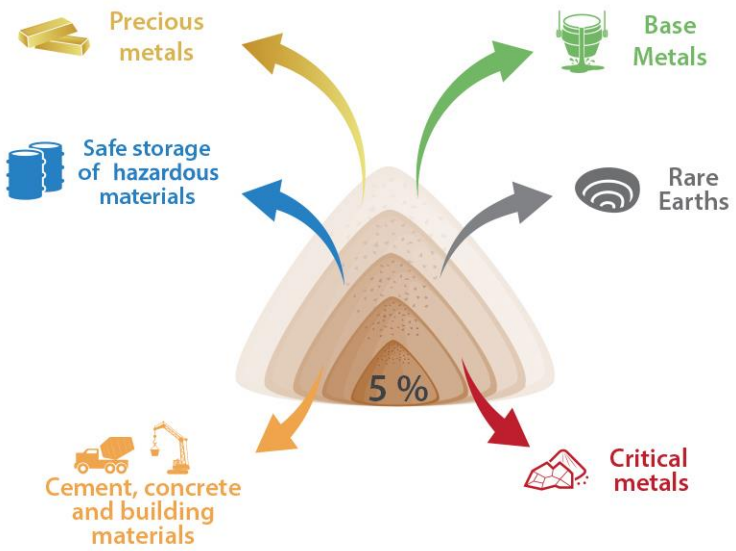
NEMO



- Near-zero-waste recycling of low-grade sulfidic mining waste (https://h2020-nemo.eu/)
- Development new ways to valorise sulfidic mining waste
- Three cases, at UoE we are looking at one case: the Sotkamo mine (Terrafame) in Finland

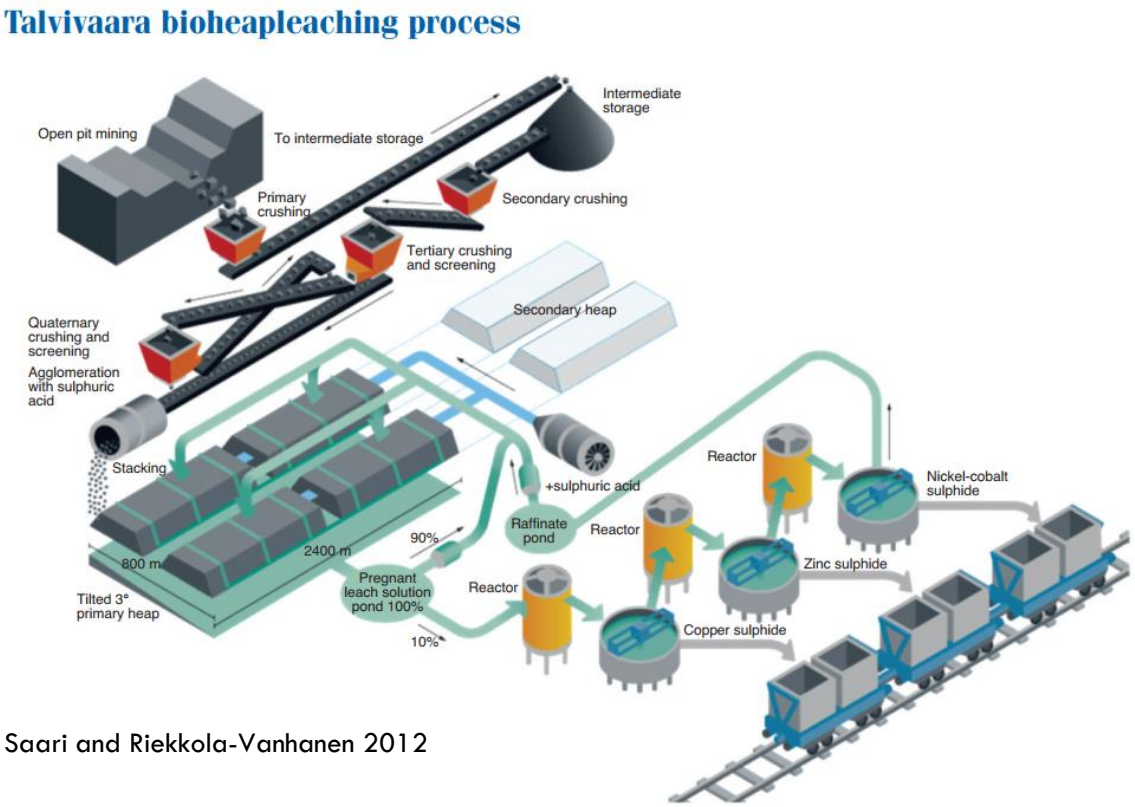
The NEMO project has received funding from the European Union's Horizon2020 research and innovation programme under grant agreement No 776846

NEMO at UoE

Simulate heap leach conditions to test process fundamentals:

- Irrigate at sensible rate to simulate solution pH and metal concentration profile across ore bed
- Study effect of nutrient addition on microbial activity
- Study effect of dissolved salt concentration on microbial activity and mineral leach rate
- Mineralogical and chemical characterization of ore and residues

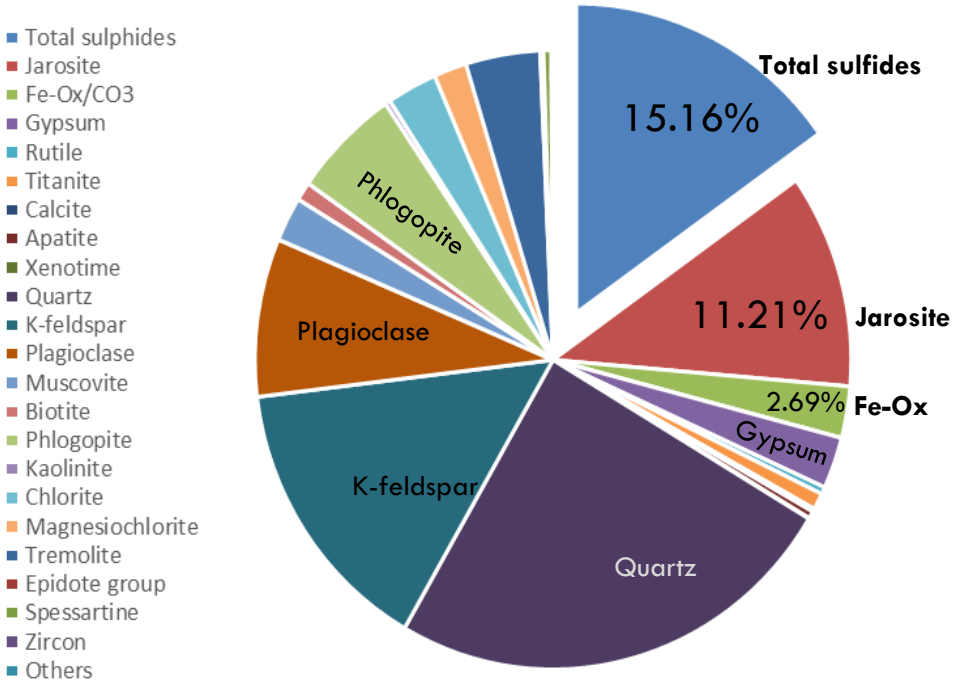
Sotkamo mine



Saari and Riekkola-Vanhanen 2012

- Ni-Cu-Co-Zn ore
- Contains pyrrhotite, pyrite, pentlandite
- Leached in the ‘primary heap’
- Moved to a ‘secondary heap’
- The irrigation solution at Sotkamo is a mixture of PLS and water.

Mineralogical composition of secondary ore by QEMSCAN



Sequential extraction

	Co %	Cu %	Mn %	Ni %	Zn %	
Step 1						**Water soluble**
Step 2						Acid soluble
Step 3						Acid/Bio soluble
Step 4						Acid/Bio soluble
Step 5						Bioleached oxidative soluble
Step 6						Bioleached oxidative soluble
Step 7						Unleachable

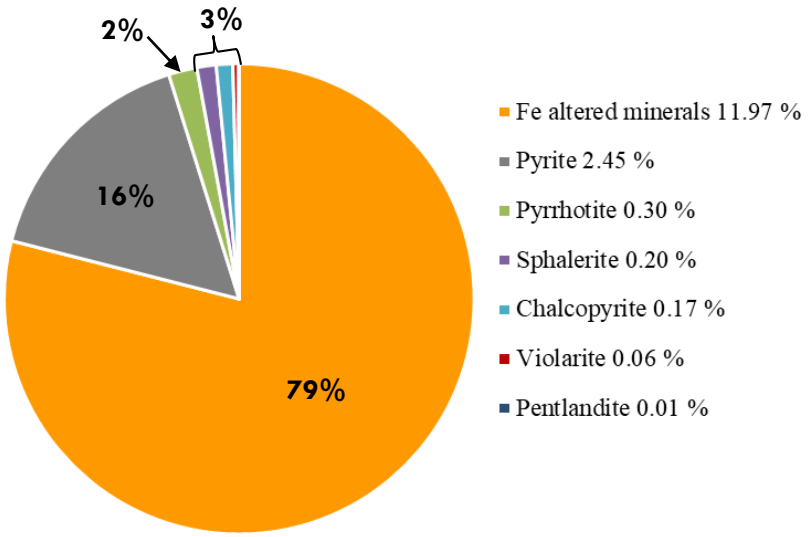
→ High concentration of metal in the water-soluble phase that dissolves when preparing sample for QEMSCAN

Dold (2003). Speciation of the most soluble phases in a sequential extraction procedure adapted for geochemical studies of copper sulfide mine waste. Journal of Geochemical Exploration 80, pp 55-68.

Sulfide mineralogy of secondary ore

Hubau A, Guezennec A-G, Joulian C, Falagán C, Dew D, Hudson-Edwards KA. Bioleaching to reprocess sulfidic polymetallic primary mining residues: Determination of metal leaching mechanisms. Hydrometallurgy. 2020 Nov 1;197:105484.

Mass distribution of sulfide minerals (%)

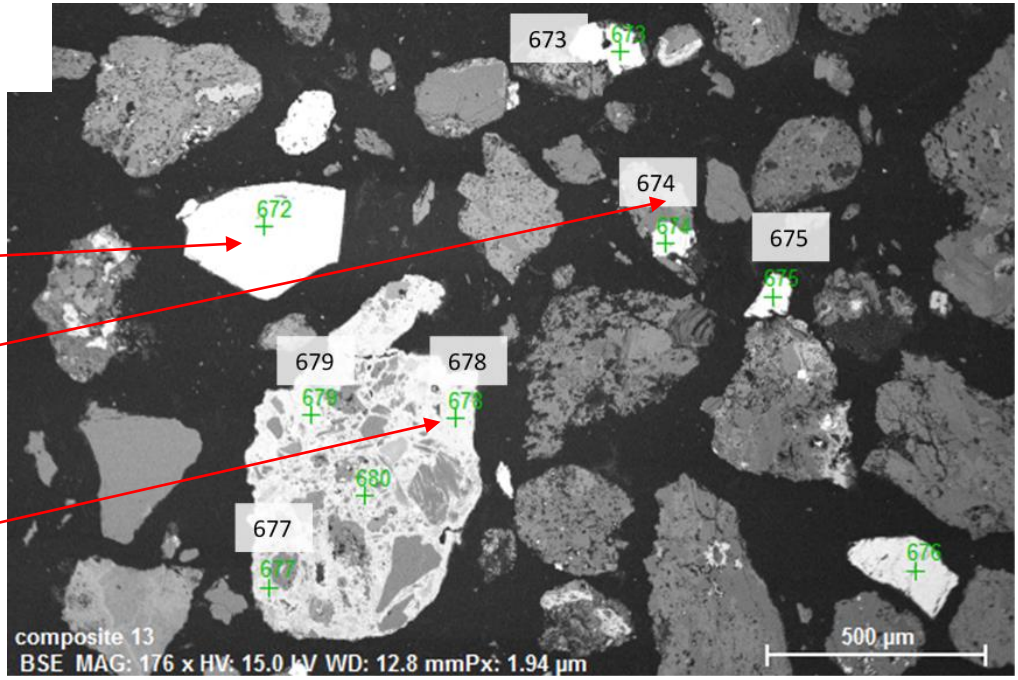


Analyses by SEM-EDS confirmed QEMSCAN results. Further studies are carried out to define the composition of the Fe altered minerals.

QEMSCAN: Pyrite
SEM-EDS: Pyrite

QEMSCA: Chalcopyrite
SEM-EDS: Chalcopyrite

QEMSCAN: **FeOx, Jarosite, Fe altered minerals**
SEM-EDS: **Schwertmannite?**



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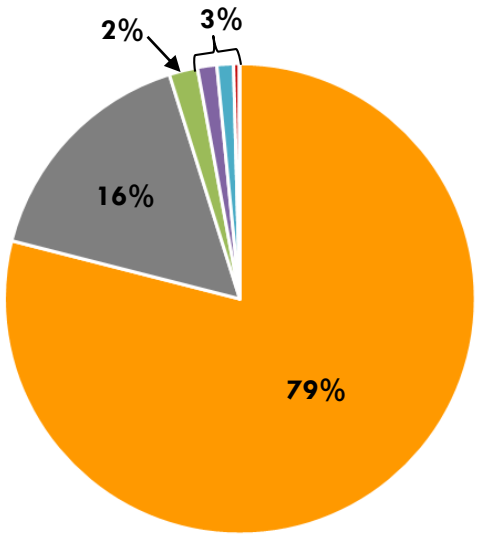
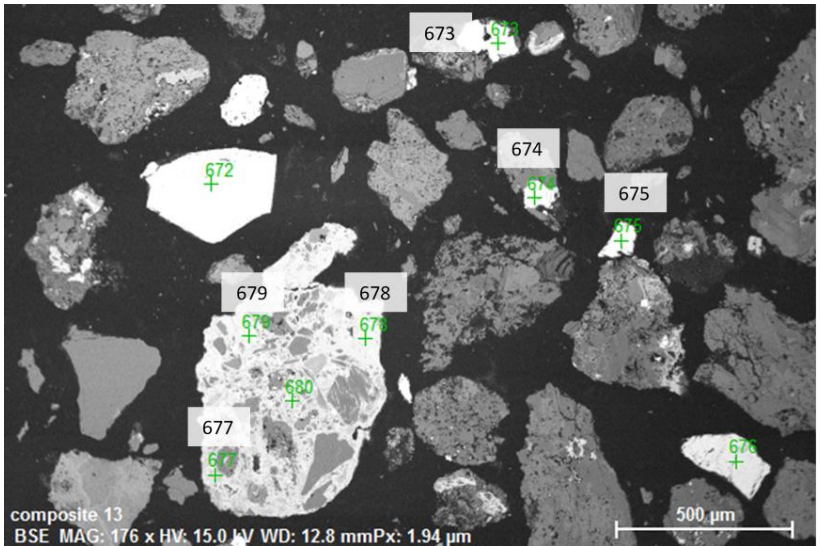
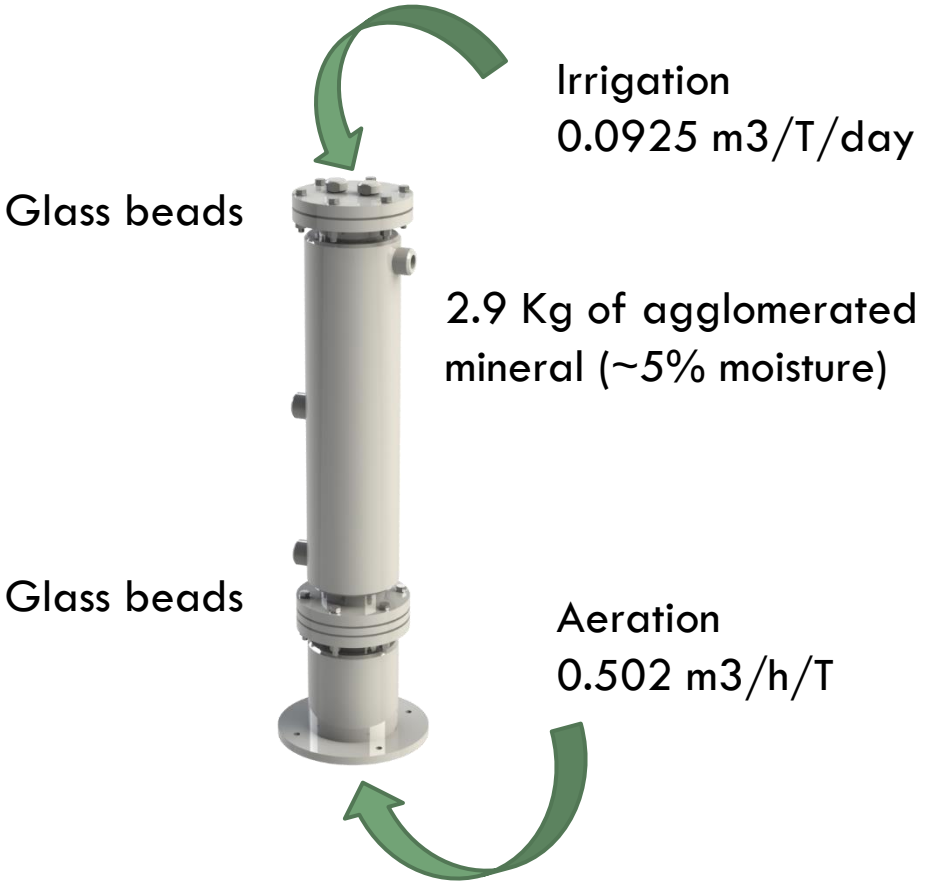


- Fe altered minerals 11.97 % Cu, Co, Ni, Zn
- Pyrite 2.45 % Co
- Pyrrhotite 0.30 % Cu, Co
- Sphalerite 0.20 % Zn, Mn
- Chalcopyrite 0.17 % Cu
- Violarite 0.06 % Ni, Co
- Pentlandite 0.01 % Ni

Fe-Ox – Cu, Co, Zn, Ni



Column experiments set-up

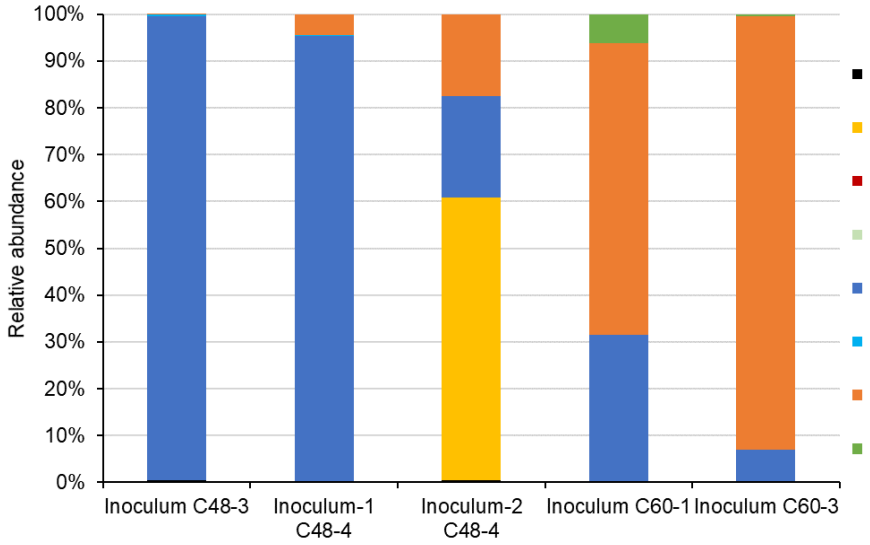


Column experiments settings

	C48-3	C48-2	C48-4	C60-1	C60-2	C60-3
Temperature	48°C	48°C	48°C	60°C	60°C	60°C
Inoculation	Y	N	Y	Y	N	Y
pH	1.2	1.1	1.3	1.2	1.1	1.3
Nutrients	Y	N	Y	Y	N	Y
Fe(II)	1 g/L	1 g/L	1 g/L	1 g/L	1 g/L	1 g/L
Synthetic raffinate*	N	N	Y	N	N	Y

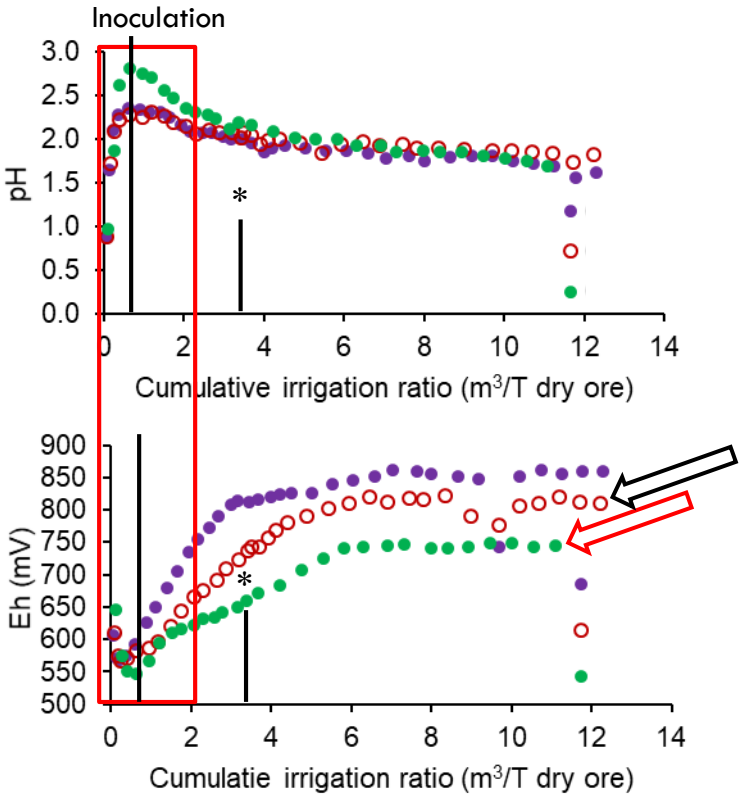
Column experiments inoculation

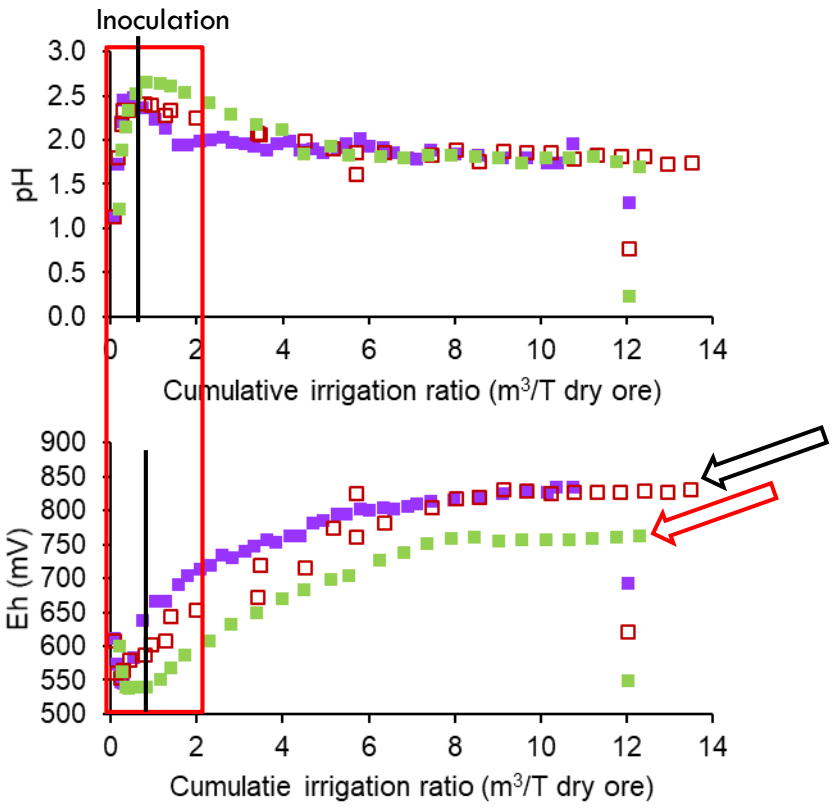
- Columns (C48-3, C48-4, C60-1 and C60-3) were inoculated at a week after starting (cumulative irrigation ratio 0.4 – 0.6 m^3/T ore)
- C48-4 was inoculated a second time after 48 days from the start of the experiment (cumulative irrigation ratio 3.7 m^3/T ore)
- Cultures used to inoculate columns irrigated with 100% synthetic raffinate (C48-4 and C60-3) where cultivated in the presence of Mg and Al as sulfate salts



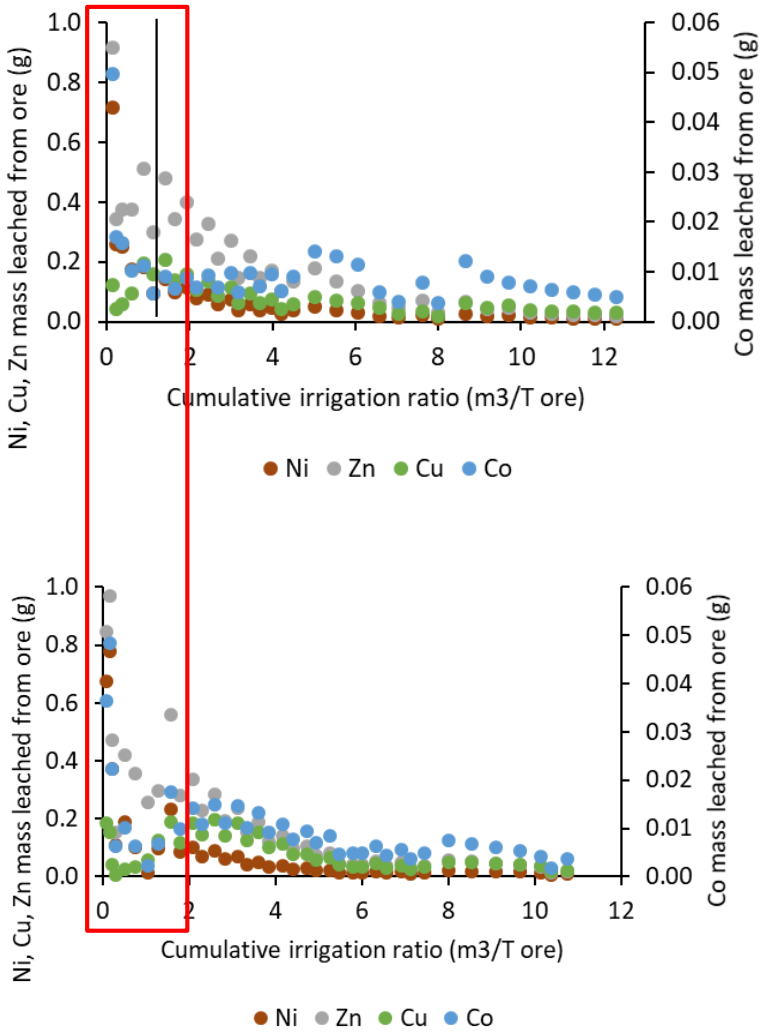
Results: pH and redox

- First irrigation period characterized by drainage solution with high pH and low redox
- Drainage solution pH at the end of experiment similar in all columns
- No inoculated columns show similar redox than inoculated columns when irrigated with no raffinate
- Drainage solution redox lower in columns irrigated with synthetic raffinate



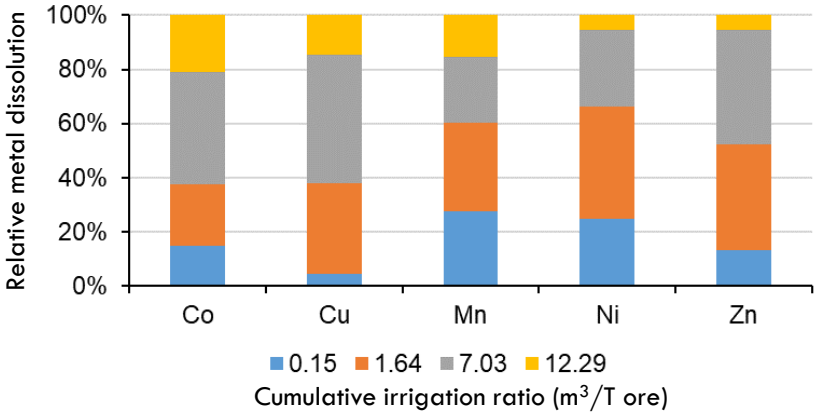


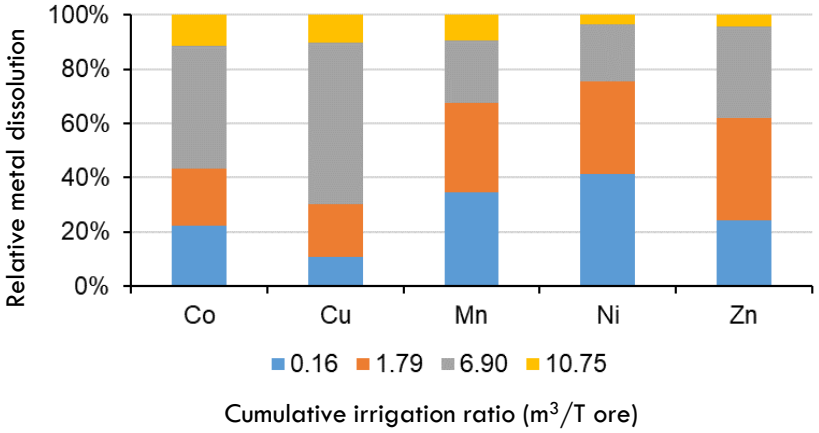
Results: metal dissolution



- Similar metal dissolution profiles in all columns
- High dissolution of metals at the beginning of the experiments

Results: metal dissolution

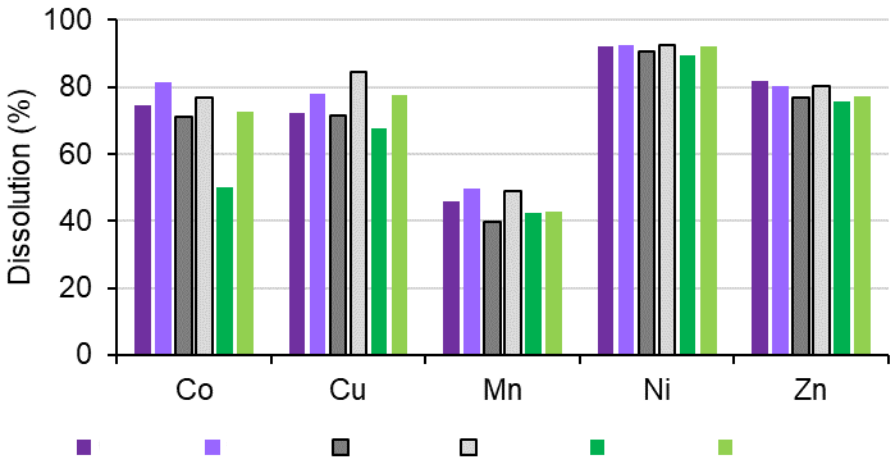




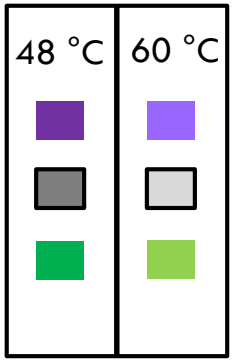
- Initial high release of metals → Water soluble fraction (sequential extraction)
- 60-65 % of Ni and 50-60% of Zn are leached during the acid dissolution phase
- Only 38-42% of Co and 30-38% of Cu are leached during the acid dissolution phase

		Co	Cu	Mn	Ni	Zn
Sequential extraction steps		%	%	%	%	%
Step 1 + 2	Water/Acid soluble					
Step 3 + 4	Acid/Bio soluble					
Step 5 + 6	Bioleached oxidative soluble					
Step 7	Unleachable					

Results: metal dissolution



- Ni and Zn dissolution similar in all experiments
- Lower Co and Cu dissolution at 48 °C
- Lowest Co and Cu dissolution at 48 °C when irrigated with 100% synthetic raffinate



Nutrients + Inoculum

No Nutrients; No Inoculum

Nutrients + Inoculum + 100 % synthetic raffinate

		Co	Cu	Mn	Ni	Zn
Sequential extraction steps		%	%	%	%	%
Step 1 + 2	Water/Acid soluble					
Step 3 + 4	Acid/Bio soluble					
Step 5 + 6	Bioleached oxidative soluble					
Step 7	Unleachable					

Conclusions

- Conclusions to be found in paper in preparation.
- This presentation will be updated when the paper is published.
- If you want more information or are interested in collaborating with us you can find our email in the first slide of the presentation.

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Acknowledgments

Terrafame: https://www.terrafame.com/terrafame-ltd.html

FGM: https://www.mineralsgroup.fi/

CSM tech team: http://emps.exeter.ac.uk/csm/facilities/

ESI tech team: https://www.exeter.ac.uk/esi/

Wheal Jane laboratories: https://www.wheal-jane-laboratory.co.uk/

And you!

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