LIGHTS - Lightweight Integrated Ground and Airborne Hyperspectral Topological Solution

How technologies from the ERA-MIN projects reduce environmental and social impacts?

Online SUMEX Clustering Workshop
15-16 June 2021

Ana Teodoro and Alexandre Lima, Univ. of Porto and Jean Cauzid, Univ. of Lorraine

The role of Remote Sensing

- Remote sensing has been applied in geology since the early 70's and it is a **powerful resource to delineate target exploration areas** for several deposit types.
- Only **recently**, these methodologies have been used to the **detection of lithium** (Li)-bearing pegmatites.

- Growing importance and demand of Li for the construction of Li-ion batteries for electric cars and battery storage.

The Lights project aims at fusing data at all scales in near-real time with artificial intelligence algorithms in order to speed up the exploration process at the target scale. It uses remotely-sensed (satellite, drone, tripod) and ground-acquired (handheld tools, geological observations, laboratory devices) data.

Presentation focussed on remote sensing algorithms capable of **identifying Li-pegmatites** based on the **recognition** of the associated **alteration halos**.

Data

Data

Level 1 cloud free images with low vegetation coverage:

- Landsat 5 TM

  (02/09/1990)

- Landsat 8 OLI

  (04/09/2014)

- ASTER

  (28/06/2004)

- Sentinel-2

  (27/10/2017)

Image processing

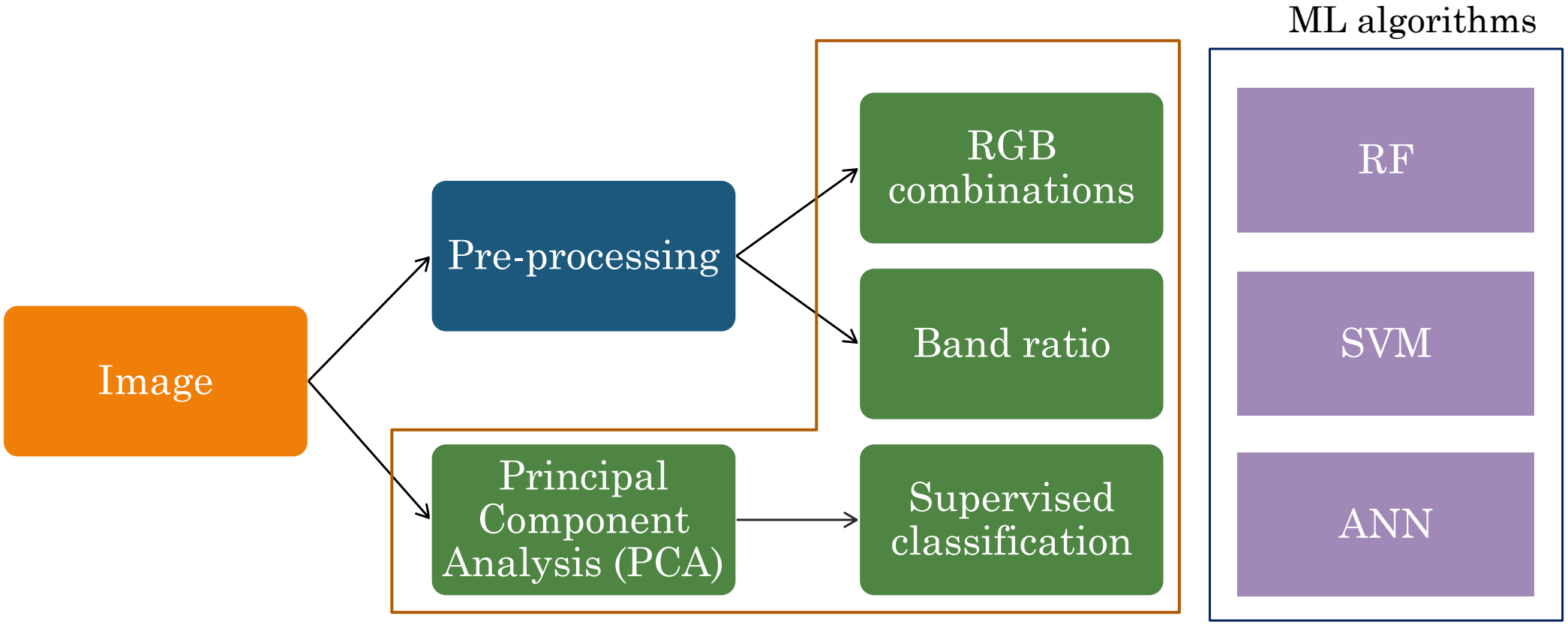
Pre-processing

- Radiometric correction
- Atmospheric correction
- Surface reflectance
- Vegetation and water mask
- Sub-setting

Processing methods

- RGB combinations
- Band ratio
- Principal Component Analysis (PCA)
- Image classification – ML algorithms

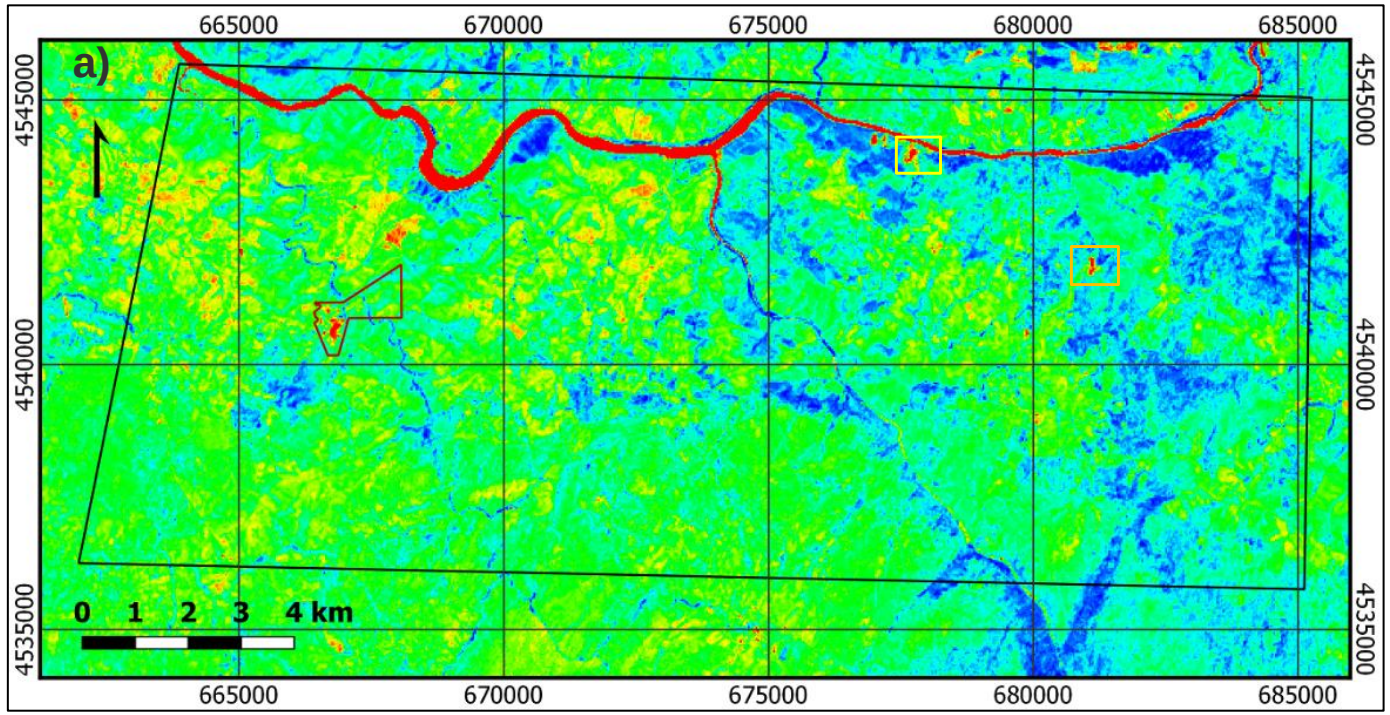
Processing Methods

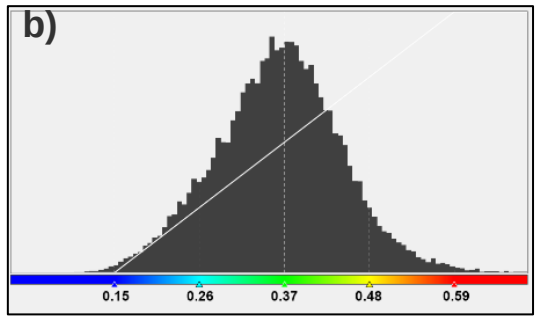


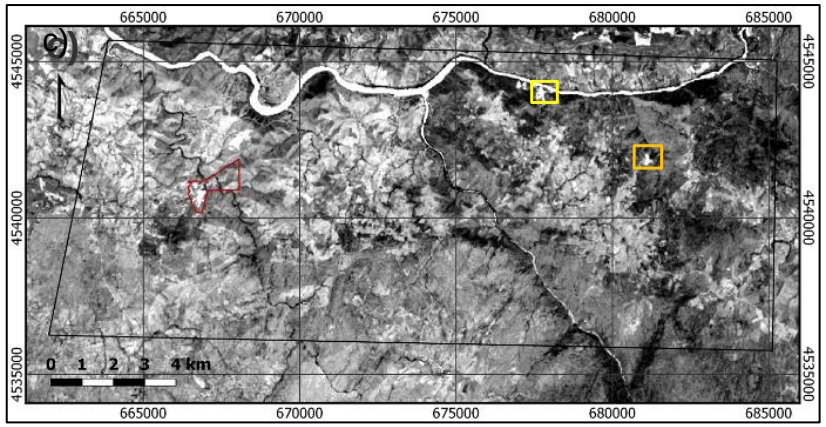
- Identify hydrothermal alteration zones
- Identify Li-bearing zones

Image processing methods

LANDSAT 8







Legend

Bajoca mining concession | Studied area | Feli mine | Alberto mine

Band ratio 3/5

(Self-proposed)

Li-mineralization mapping through band rationing.

a) Ratio 3/5 image with density slice (high ratio values shown in red);
b) Histogram for 3/5 image;
c) Landsat 8's ratio 3/5 image.

Conclusions

- RS data/techniques **reduce the destructive impacts** of some prospective actions.
- RS approach reduce **time and costs** and allowed to identify pegmatites in area with low vegetation coverage.

There is a great potential for the discrimination of Li-bearing zones using satellite based remote sensing.

Satellite RS can help reducing the areas on which further exploration has to be done.

The exploration steps after satellite RS (drone, geological survey, handheld tools) will generate more interactions with the inhabitants of the targeted areas.

Results - Published Work

- Joana Cardoso-Fernandes, João Silva, Filipa Dias, Alexandre Lima, Ana C. Teodoro, Odile Barrès, Jean Cauzid, Mônica Perrotta, Encarnación Roda-Robles, Maria Anjos Ribeiro, (2021). Tools for remote exploration: a Lithium (Li) dedicated spectral library of the Fregeneda-Almendra aplite-pegmatite field. Data, 6, 33.

- Cardoso-Fernandes, J., Teodoro, A.C., Lima, A., Roda-Robles, E. (2020). Semi-automatization of support vector machines to map lithium (Li) bearing pegmatites. Remote Sensing 12(14), 2319.

- Cardoso-Fernandes, J., Teodoro, A.C., Lima, A., Perrotta, M., Roda-Robles, E. (2020). Detecting Lithium (Li) mineralizations from space: Current research and future perspectives. Applied Sciences (Switzerland)10(5),1785.

- Cardoso-Fernandes, Lima, J., Roda-Robles, Teodoro, A.C. (2019). Constraints and potentials of remote sensing data/techniques applied to lithium (Li)-pegmatites. Canadian Mineralogist, Vol. 57, Issue 5, 723-725. DOI:10.3749/canmin.AB00004.

- Cardoso-Fernandes, J., Teodoro, A.C., Lima, A.M.C. (2019). Remote sensing data in lithium (Li) exploration: A new approach for the detection of Li-bearing pegmatites. International Journal of Applied Earth Observation and Geoinformation 76:10-25. DOI: 10.1016/j.jag.2018.11.001.

nanoBT

Application of **nano-b**ubble **t**echnologies to mining industry operations

ERA·MIN 2
RESEARCH & INNOVATION PROGRAMME ON RAW MATERIALS TO FOSTER CIRCULAR ECONOMY

KEY TECHNOLOGOCAL DEVELOPMENTS (involving the use of nanobubbles):

WP5 – Development and testing of high capacity nanobubbler *(FBT)*

WP4 – Phytostabilization and phytoextraction (toxic metal spoils) *(TU-Crete)*

WP3 – Treatment of effluents (tailing ponds) – recovery of water and residual metals *(U Laval)*

Project duration: Dec 2020 – Nov 2023

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fine bubble technologies
...as nature intended

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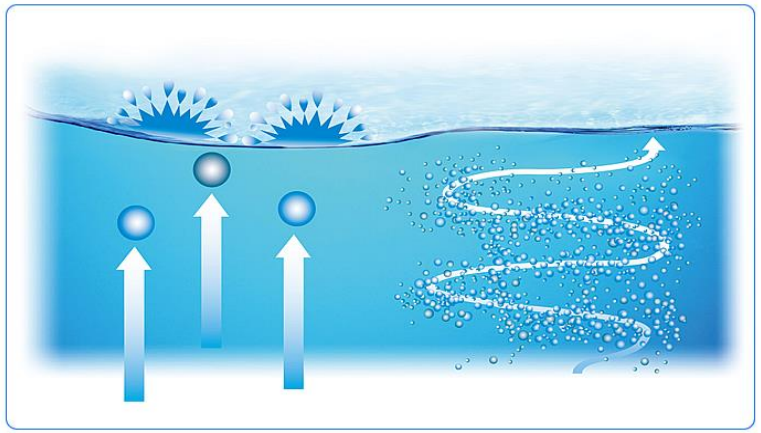
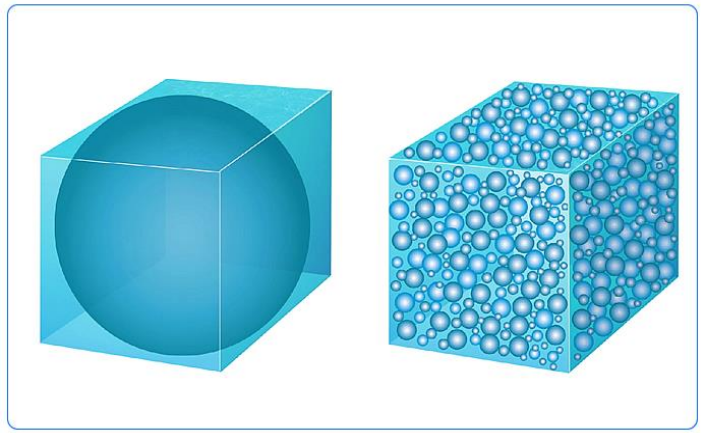
Environmental applications of nanobubbles (NBs)

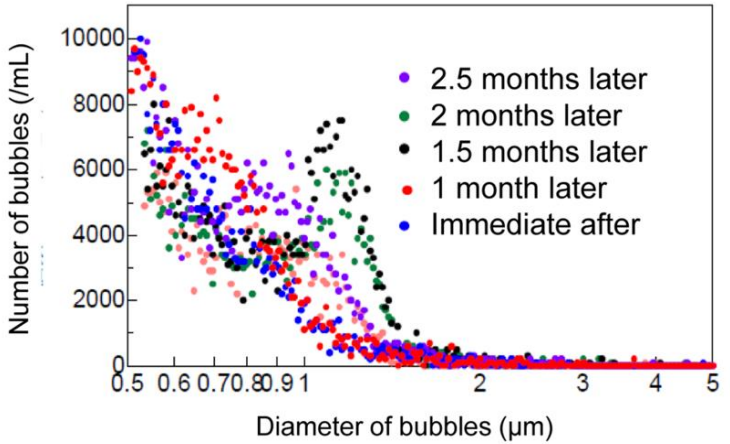
Buoyancy is almost negligible...



Interfacial area is extremely larger...



NBs stay in the liquid phase - They are there after 2.5 months!!!!



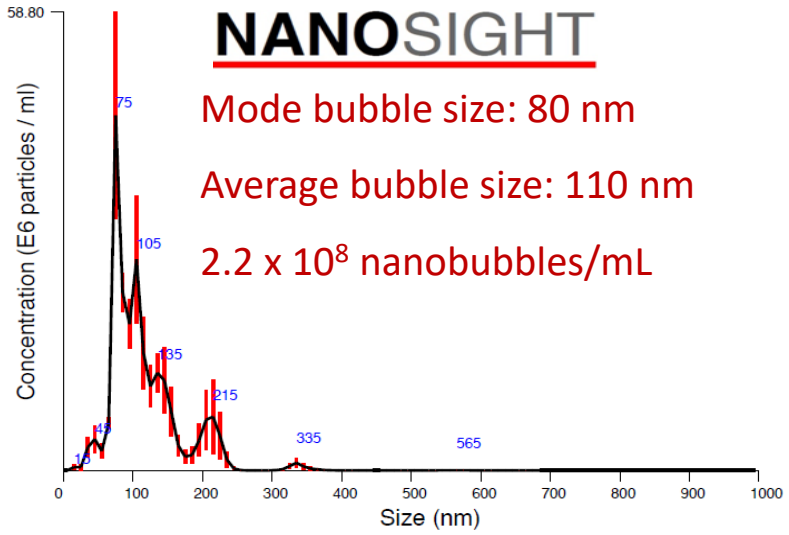
Emirates Golf Club - Dubai (algal blooms)

Westlake Golf Club irrigation pond (Cape Town)

Kalogerakis et al., "Environmental applications of NBs...", *Can. J. Chem. Eng.* (June 2021)

Development and testing of high capacity nanobubbler (WP5)

MK1 nanobubbler™ (submerged unit)



Mode bubble size: 80 nm

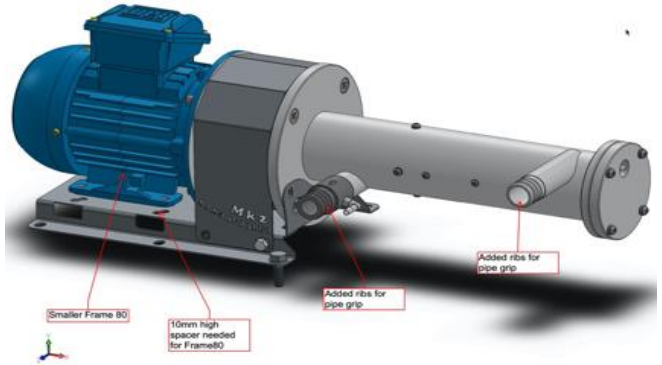
Average bubble size: 110 nm

2.2 x 10^8 nanobubbles/mL

Averaged FTLA Size / Concentration
Red error bars indicate +/- 1 standard error of the mean

Tulbagh winery (S. Africa) wastewater pond

MK2 nanobubbler™ (external)



MK-mega nanobubbler™ (submerged)
At >10 times capacity

To be developed and tested by FBT in years 2 & 3

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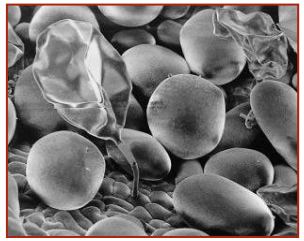
...as nature intended

Phytostabilization and phytoextraction (toxic metal spoils) (WP4)

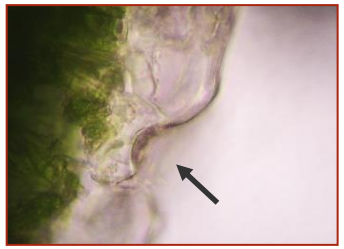
Explore the efficiency of **phytostabilization and phytoextraction** technology to remediate toxic metal spoils (from LARCO S.A.) using halophytic plants + biochar + nano-bubbled irrigation water.

The effect of these factors will be examined:

1. Ability of the plants to remove or/and stabilize the metals
2. Effect of biochar application
3. Effect of irrigation with air nanobubbles supplemented water
4. Combined effect (biochar + NB-irrigation)



Salt bladders of *Atriplex*



Salt gland of *Tamarix*

Phytoexcretion of metals through the salt glands of halophytes…

Quantify the effect of nanobubble irrigation on Metal Phytoexcretion

Halimione portulacoides

Tamarix parviflora

Limoniastrum monopetalum

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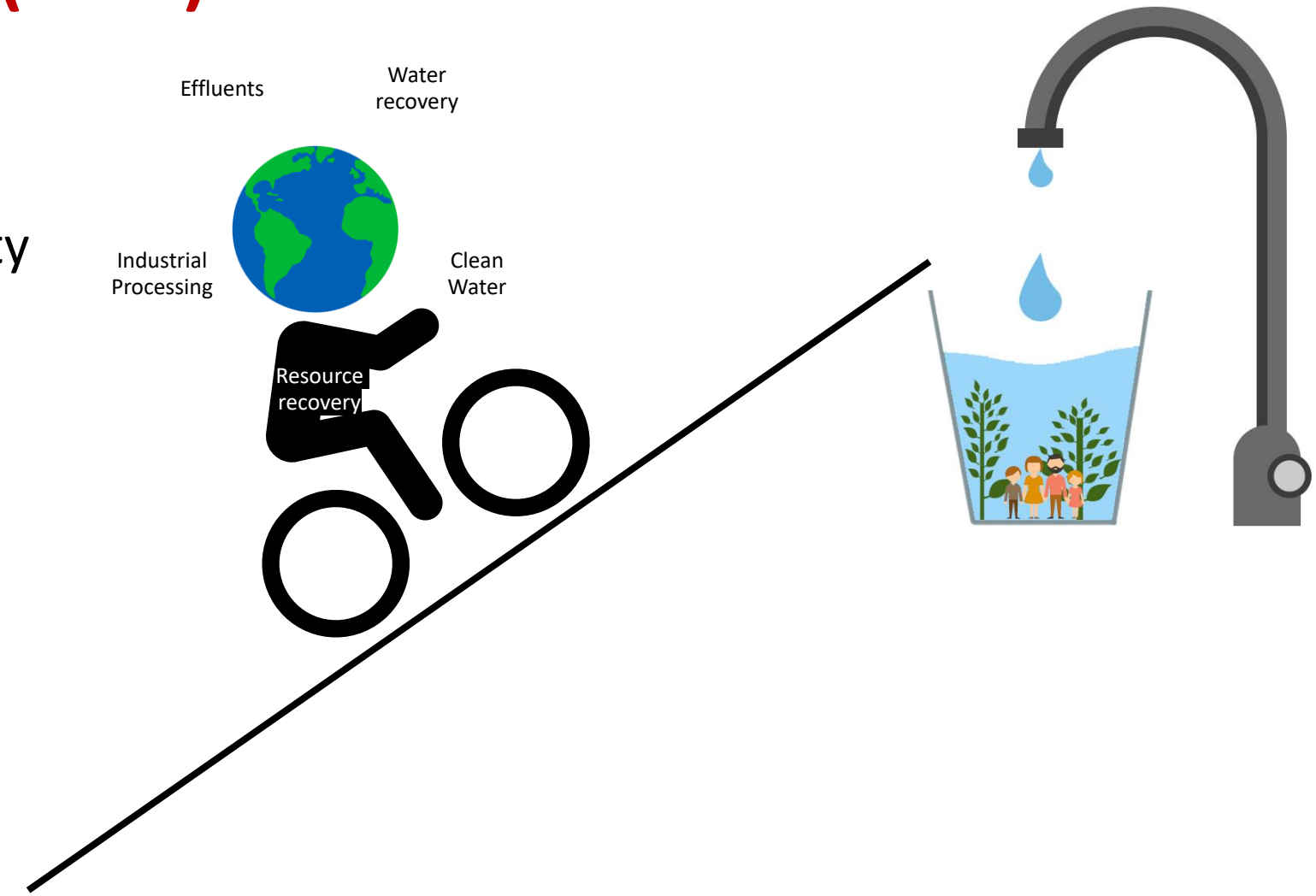
Treatment of effluents (tailing ponds) – recovery of water and residual metals (WP3)

- protect the environment
- safeguard health and prosperity
- reduce accidents and liabilities
- provide access to clean water
- tailings valorization



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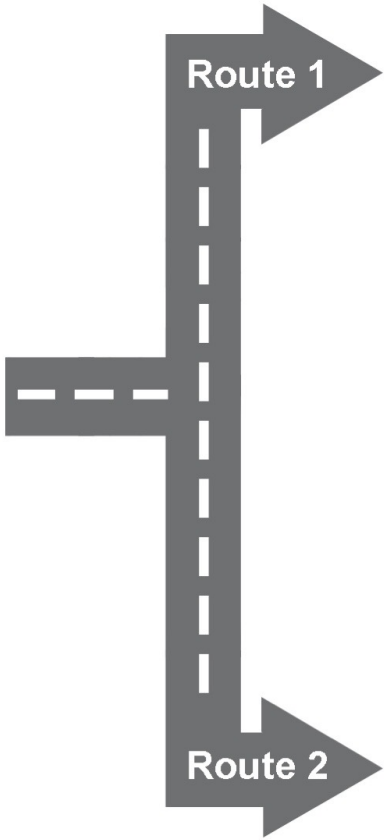
Tackling a billion m^3 wastewater problem with climate-driven processes and nanobubbles



Treat aqueous mining wastes with cold CO_2 nanobubbles to recover clean water in the form of ice-like products (i.e., gas hydrates)

Outcomes

Clean water

from effluents and tailings

prior to discharge

Use low-cost, biodegradable, green, anhydrous solvents to selectively recover metals and minimize waste generation as well as water and acid consumption

Outcomes

No more effluents

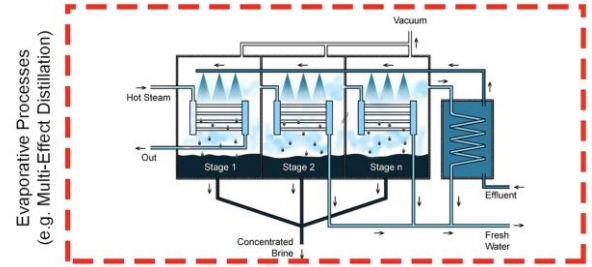
Change the chemistry!

No need for end of pipe treatment!

WP3 – Treatment of effluents (tailing ponds)

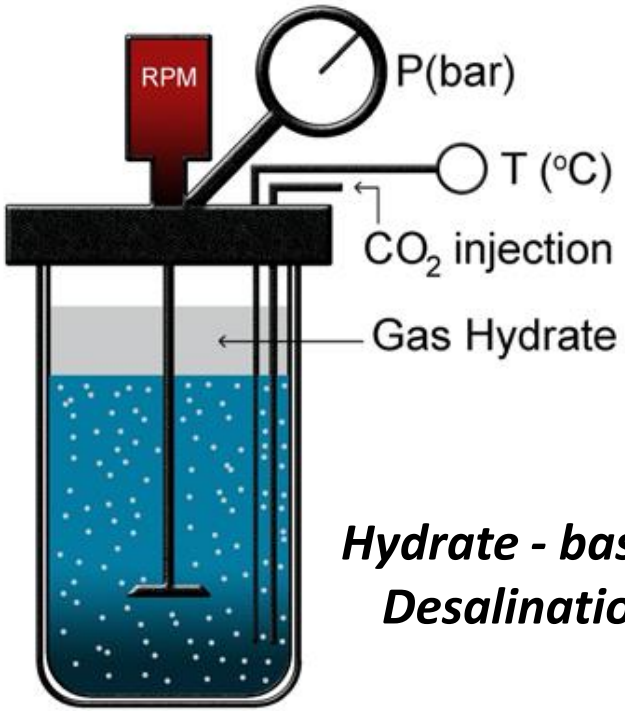
1. Recovery of water

Evaporation processes



Climate-driven technologies

- *freezing 7 times less energy vs. evaporation!*
- *nanobubbles enhance hydrate kinetics*

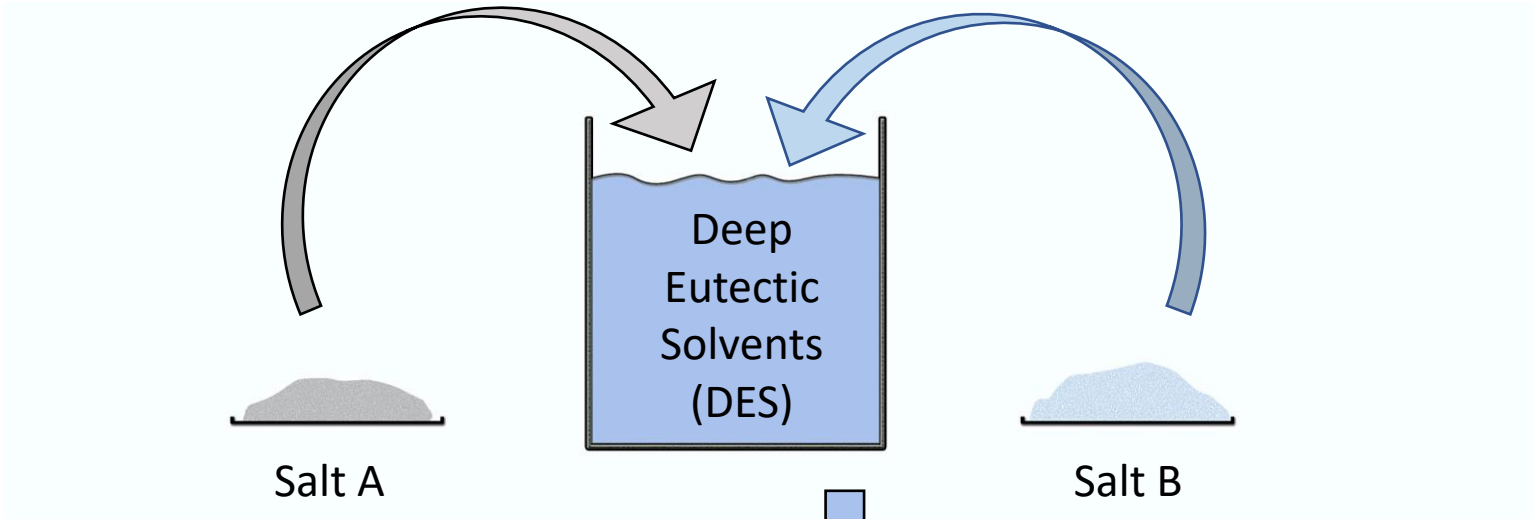


Hydrate - based Desalination

WP3 – Treatment of effluents (tailing ponds)

2. Recovery of residual metals

And what do we do with the brines?



- Water free
- NO MORE effluents and tailings

Change the chemistry!

No need for end of pipe treatment!

sustainable metal recovery to finance remediation

Project nanoBT: Research Contributions

ERA·MIN 2
RESEARCH & INNOVATION PROGRAMME ON RAW MATERIALS TO FOSTER CIRCULAR ECONOMY

- **Recover water and metals** based on climate- and phytoremediation-driven technologies
- Develop **novel sustainable zero-waste extractive metallurgy** processes to recover residual metals and finance the remediation
- **Exploit the power of nanobubbles** to solve a mega billion m^3 aqueous waste problem

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IMPROVE RESOURCE EFFICIENCY AND MINIMIZE ENVIRONMENTAL FOOTPRINT (REMINE)

Lina Hällström

Luleå University of Technology, Sweden

LULEÅ UNIVERSITY OF TECHNOLOGY

REMinE (2016-2019)

SWEDEN:	**PORTUGAL**	**ROMAINIA**
Luleå University of Technology	Porto University	National Institute for Metals and Radioactive Resources
Total requested funding:		
▪ 639 257 EURO	151 000 EURO	249 200 EURO
Total cost:		
▪ 752 526 EURO	151 000 EURO	249 200 EURO

Yxsjöberg, Sweden

- Be, Bi, F, W
- 1918-1963
- Stored open to the atmosphere

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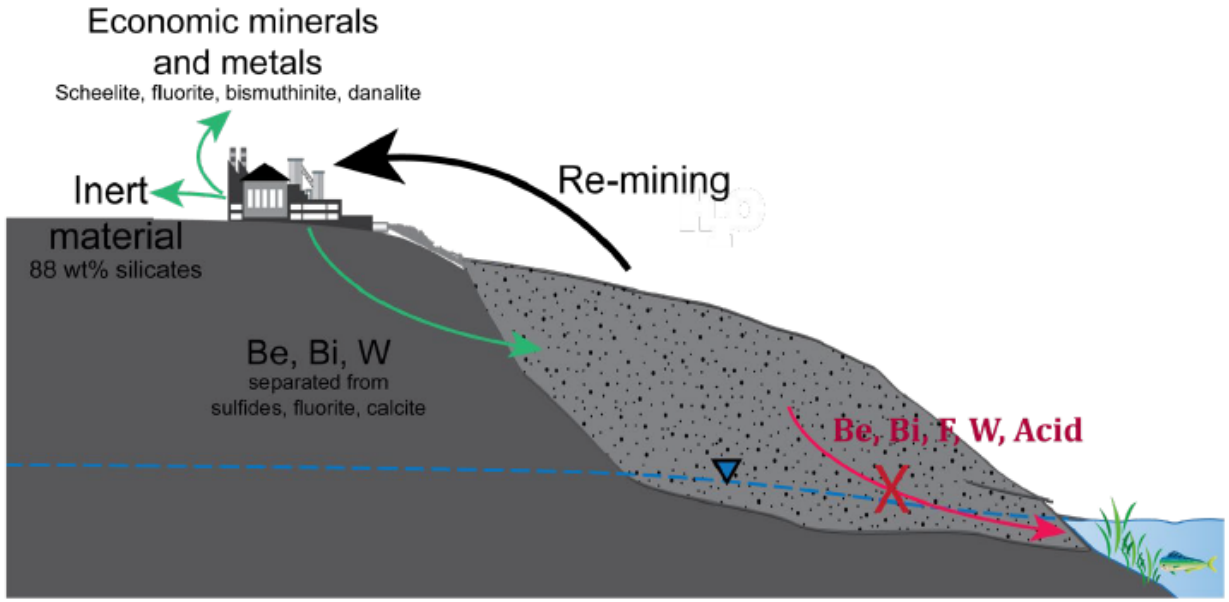
SUSTAINABILITY

- Re-mining historical tailings
  - Economic benefit (EU-critical raw materials)
  - Environmental benefit (geochemistry and toxicity of critical metals)
  - Social benefit (Taking care of old environmental problems)



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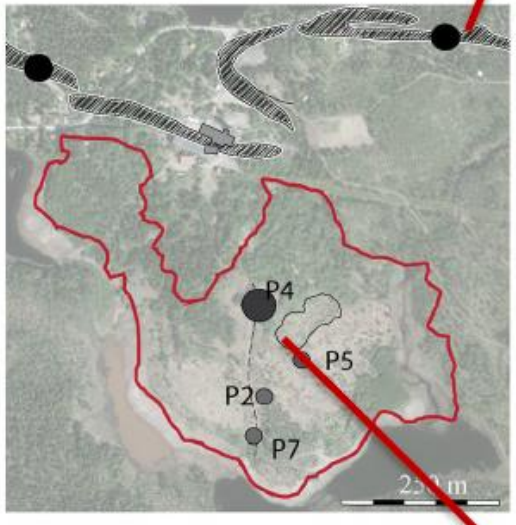
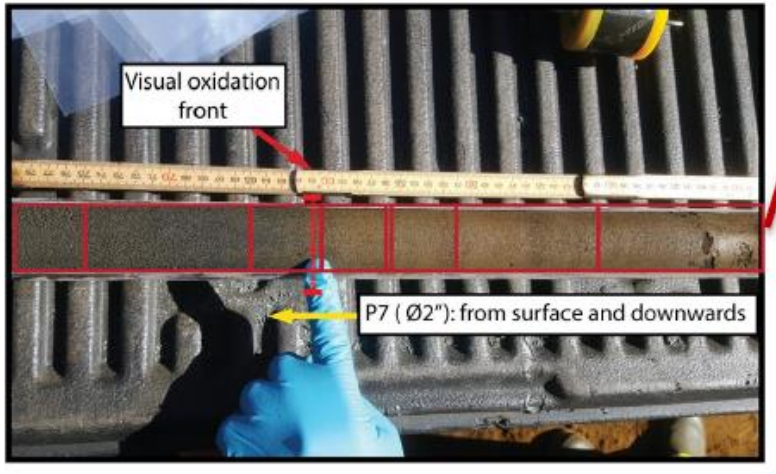
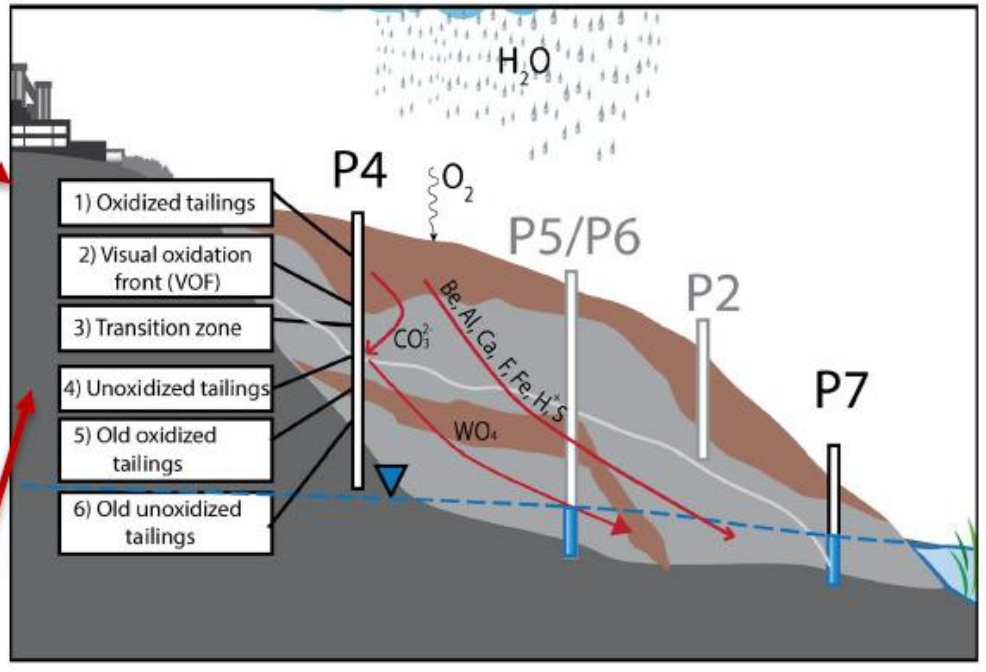
Environmental Mineralogy: geochemistry and mineralogy

Rock drilled cores



Intact tailings core samples





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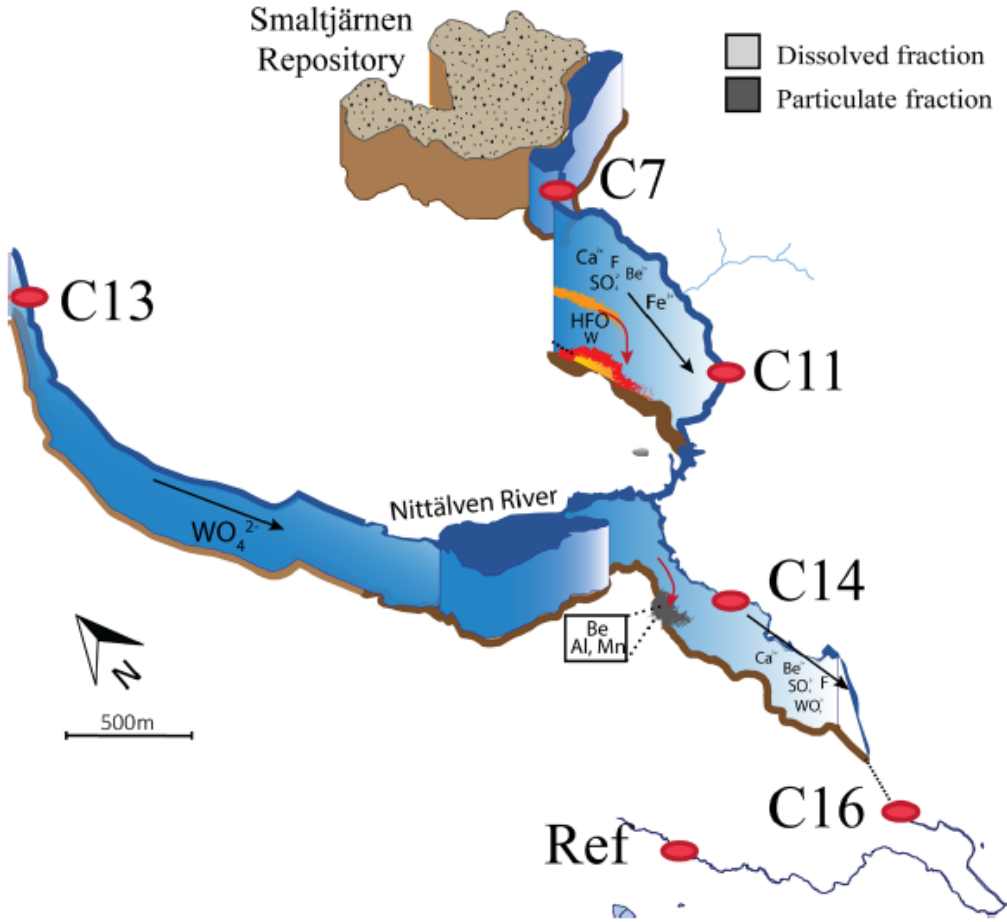
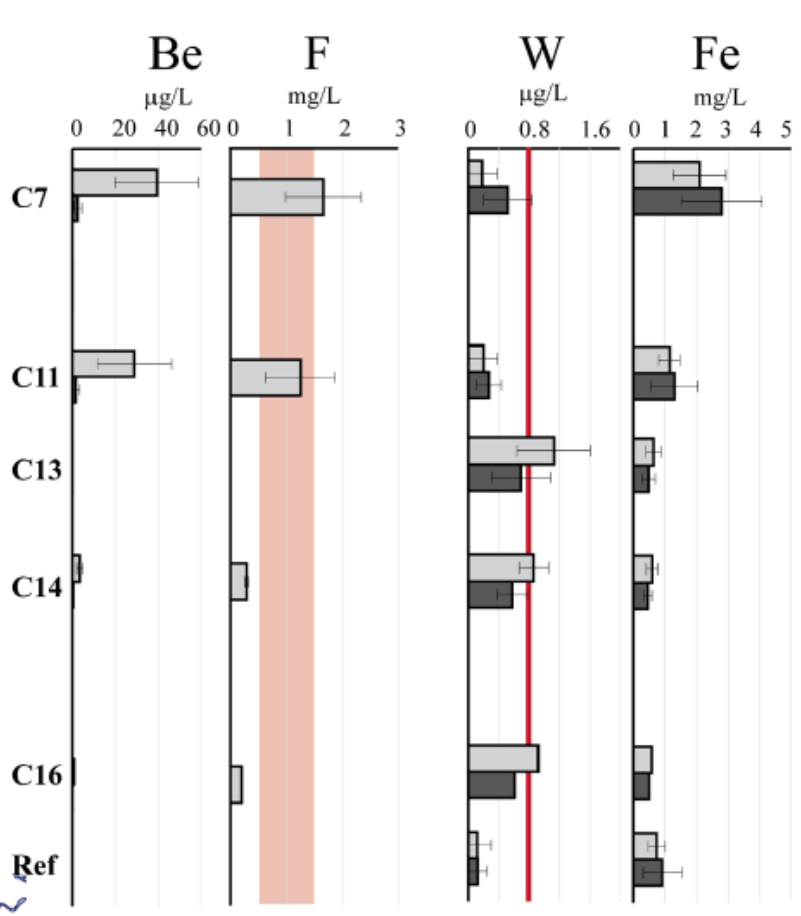
Environmental forensics: tracing pollutions to the source





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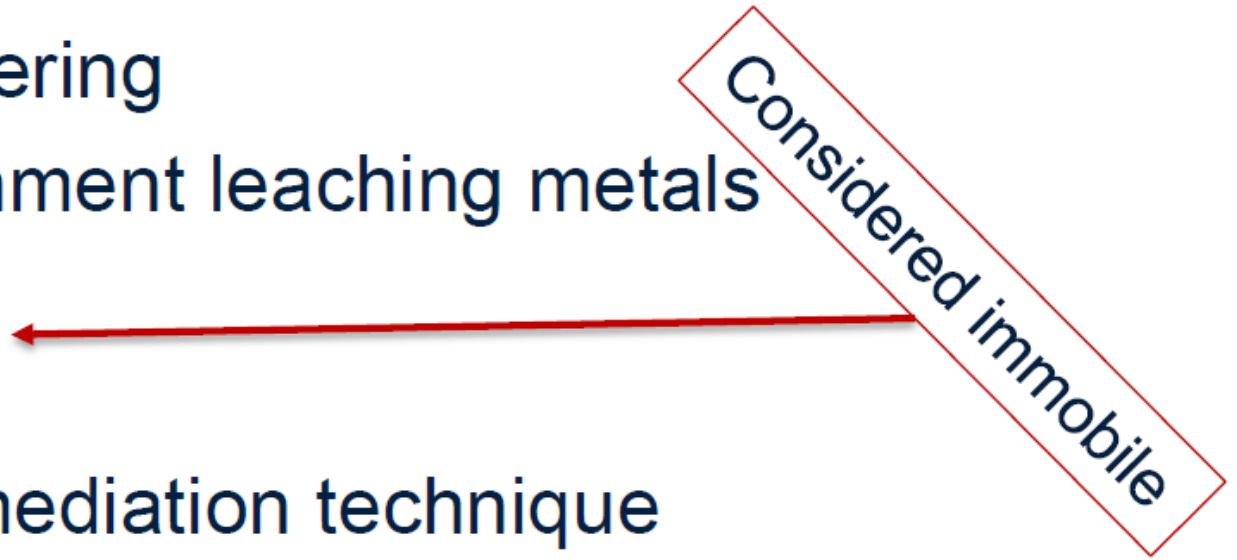
ENVIRONMENTAL IMPACT

- Determine the phase of weathering
- Show the geochemical environment leaching metals
  - Oxic environment – Be & F
  - Anoxic environment – W
- Help to choose the correct remediation technique
  - Cover and water saturation is not suitable
  - Decrease metal release with Re-mining



<u>IMPORTANT FOR SUSTAINABLE MINE WATER AND WASTE MANADGEMENT</u>

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Re-mining

- Re-mining can not only consider the economic benefit
- Can be used as a REMEDIATION METHOD, If:
  - ”All” metals are extracted
    - Secondary minerals scavanging metals
  - The new waste is environmentally safe
- New technologies that extract the metals/minerals
- Consider: volumne of waste, mobile processing plants

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Referenser

- Hällström L.P.B., Salifu M., Alakangas L., Martinsson O. (2020) The geochemical behaviour of Be and F in historical mine tailings of Yxsjöberg, Sweden. J. Geochem. Explor. 218, 106610.
- Salifu, M., Hällström, L., Aiglsperger, T., Mörth, C. M., & Alakangas, L. (2020). A simple model for evaluating isotopic (18O, 2H and 87Sr/86Sr) mixing calculations of mine–Impacted surface waters. Journal of contaminant hydrology, 232, 103640.
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- Salifu, M., Aiglsperger, T., Hällström, L.P.B., Martinsson, O., Billström, K., Ingri, J., Dold, B., Alakangas, L. (2018) Strontium (87Sr/86Sr) isotopes: a tracer for geochemical processes in mine wastes. Journal of Applied Geochemistry. 99, pp.42-54

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REVIVING – revisiting mine tailings to innovate metals biorecovery

@SUMEX

Coordination: University of Coimbra, Portugal

This project is developed within ERAMIN2 Program and financed by each Call Funding Agencies

REVIVING

Partners

- University of Coimbra
- National Institute of Research and Development for Biological Sciences
- CNRS & IGE Université Grenoble-Alpes
- ACPMR-Associação Cluster Portugal Mineral Resources
- Beralt Tin and Wolfram Portugal
- CUPRUMIN S.A.
- C.N.C.A.F. MINVEST SA, DEVA
- DKM Control Limitada

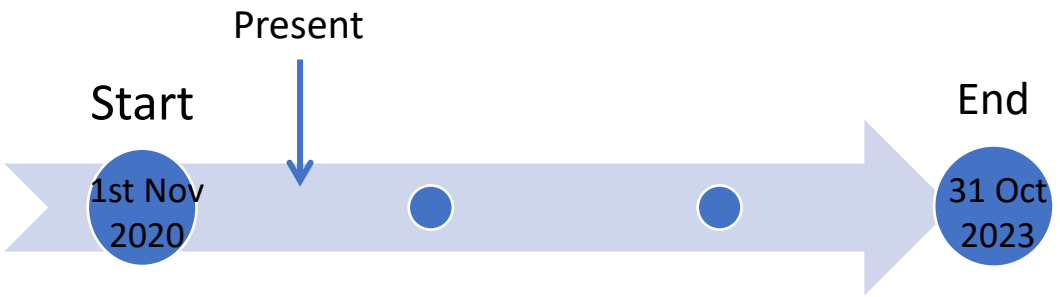
Budget

Total costs 546.366€;
Requested funding 522.793€;
Own funding 23.573€

TOPIC

3. Processing, Production and Remanufacturing

Project Timeline



REVIVING – objectives

The project is focused on valuing mine tailings as resources, supplying metals that are extracted today by other processes, promoting recycling

The project uses knowledge obtained in the ERAMIN project BioCriticalMetals (ERAMIN/0002/2015) on the microbiome of tailings

The main objective of the REVIVING project is to:

get improved models for efficiently recycling metals from residues in case-study mines, based, for the first time, on tailings autochthonous microbiome manipulation, using molecular data to promote the bioleaching-bacterial populations, and innovative hydrometallurgy using negative pressure

- **REVIVING will innovate the bioleaching process by enabling mine zero waste**
- **Recycling mine residues, soil areas will be returned to agriculture, forestry and population, increasing mine social acceptance**

REVIVING

WP1. Management

WP5. Dissimination & Communication

ERAMIN BioCriticalMetals

Geo-chemical characterization of materials

Culture collection of mine autochthonous bacteria

WP2: Mine-tailings column tests developed with Beralt (Portugal) and with CUPRIMIN (Romania)

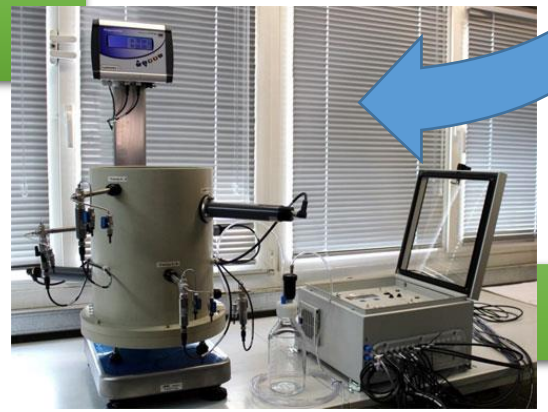
Taks1. Lab scale Field-experiments portrait

Task2. Upscaling bacteria growth

WP3: Bioleaching using lab scale lysimeter with Beralt (Portugal) and with CUPRIMIN (Romania)

Task1: Dynamics of metal enrichment between percolation and porewater

Task2. Omics-based prediction of the bioleaching microbiome



Task3. Development of the model for metal bioleaching of the wolframite mine tailings

Task2. Monitoring the experiment

Task1. Setup of the experiment in Beralt Tin and Wolfram

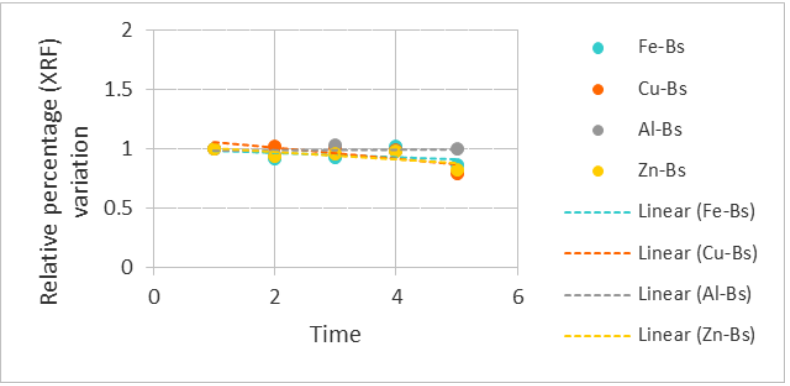
WP4: Field-Plot experiment

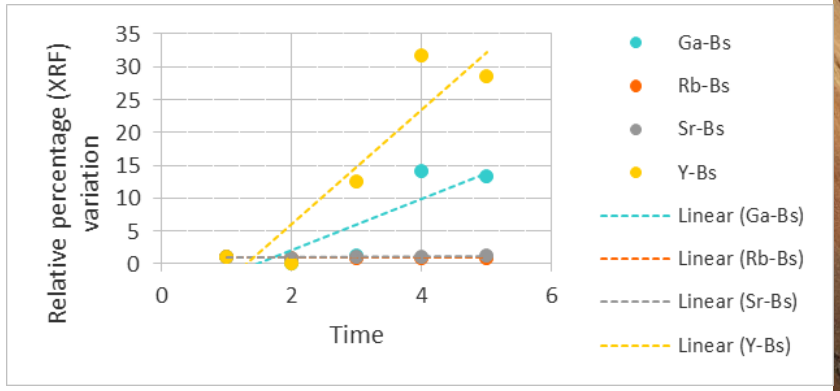
Panasqueira mine, Portugal - The case study

➢ **How does the approach and/or technology help reduce environmental and social impacts and/or address health and safety?**

Project Outcomes

- Enhance metals recovery (e.g. Cu, Zn, Mo, Mn) through recycling of residues from mine tailings;
- Increase population acceptance by contributing to solving environmental risks posed by existing mine tailings and other metal residues;
- Reduce the amount of hazardous mining waste that needs to be disposed of



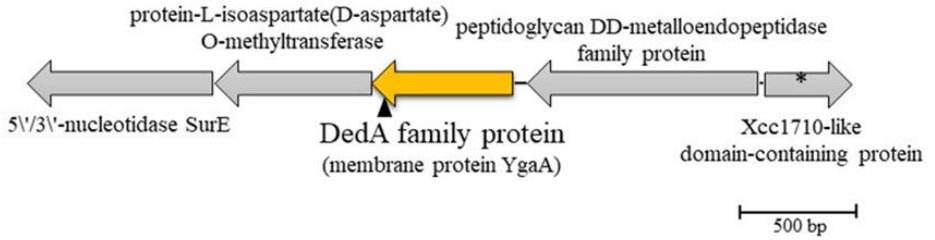


The XRF evaluation of the mine sediments after biostimulation with R2A medium showed decrease of Cu and Zn and increase in Y and Ga contents.

➢ Experiences for the uptake of the approach or technology

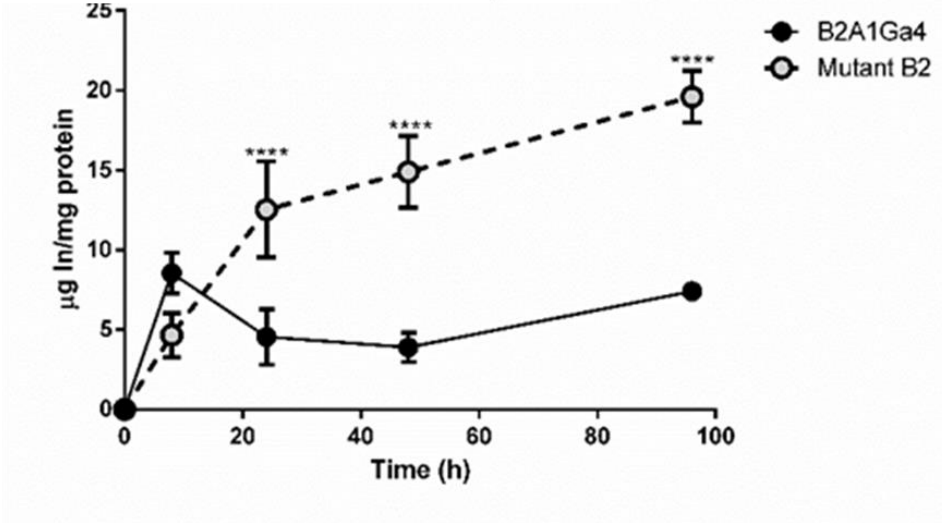
Project Outcomes

- Provide a model pilot that will facilitate technology transfer to other mine tailings
- Provide new processes for the sustainable reprocessing of tailings
- Provide EU industry access to alternative sources of critical materials stemming from European locations



Rhodanobacter sp. B2A1Ga4, isolated from tungsten mine sediments, highly resistant to heavy metals

Mutant strain, *yqaA* gene of B2A1Ga4 mutated ---> no funtional a DedA family protein --> higher accumulation of In into the cells --> great In biorecovery



Thank you

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