E R A·M I N 2

RESEARCH & INNOVATION PROGRAMME ON RAW MATERIALS
TO FOSTER CIRCULAR ECONOMY

Acronym: ERA-MIN 2
Title: Implement a European-wide coordination of research and innovation programs on raw materials to strengthen the industry competitiveness and the shift to a circular economy
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Funding scheme: ERA-NET COFUND
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Duration: 60 months

DELIVERABLE D7.1

MAIN RESULTS OF PROJECTS FUNDED BY ERA-MIN CALL 2013, 2014 AND 2015

WP 7: Joint Calls without EU co-funding
Task 7.4: Monitoring and assessment of funded project
Task Leaders: UEFISCDI and AEI
Lead beneficiary: AEI
Type: websites, etc.
Dissemination level: Public
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Due date: M39
Actual submission date: M41

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ERA-MIN 2 comprises a progressive, pan-European network of 21 public research funding organisations from 18 countries/regions (Argentina, Belgium-Flanders, Brazil, Chile, Finland, France, Germany, Ireland, Italy, Poland, Portugal, Romania, Slovenia, South Africa, Spain, Spain-Castilla y Léon, Sweden and Turkey).

Built on the experience of the EU project ERA-MIN (2011-2015), **ERA-MIN 2** aims to enhance and strengthen the coordination of research and innovation programmes in the field of non-energy, non-agricultural raw materials (construction, industrial and metallic minerals) to support the European Innovation Partnership on Raw Materials, the EU Raw Materials Initiative and further develop the raw materials sector, in Europe and globally, through funding of transnational research and innovation (R&I) activities.

ERA-MIN 2 will support demand driven research on primary and secondary resources, and substitution of critical raw materials under a circular economy approach, to give the opportunity to the R&I community to apply to world-wide coordinated funding, gaining access to leading knowledge and new markets, while reducing fragmentation of R&I funding across Europe and globally. This will be achieved through one EU co-funded call for R&I proposals in 2017 and two additional calls, in 2018 and in 2019, designed and developed specifically for the non-energy, non-agricultural raw materials sector.

Publishable summary: The report contains the list of the projects selected for funding under ERA-MIN Joint Call 2013, 2014 and 2015. It includes the call statistics, data on each project and their main outputs that could be up-taken by stakeholders (academia, industry, society). This information is public and available at the ERA-MIN 2 website.

Co-funded by the Horizon 2020 programme
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ERA-MIN Joint Call 2013 Results:

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Joint Call 2013 results: Summary Reports

Five ERA-MIN funding agencies, **FCT (Portugal), NCBR (Poland), TEKES (Finland), UEFISCDI (Romania) and VINNOVA (Sweden)**, committed together a total of €3.9 million of national public funds to support their national participants in the selected transnational R&D proposals submitted to the **first ERA-MIN Joint Call 2013.**

18 full proposals were submitted in total from 67 participants. Out of the 18 proposals, 14 passed the eligibility check. After evaluation and ranking, 4 transnational projects, involving 19 organisations, were finally selected for funding: project acronyms **CELMIN, GEOSULF, MAXI and SUSMIN**. The total project funding was €2.9 million and the total costs were €3.9 million. The total success rate of the Joint Call 2013 was 22.2% (4 funded/18 submitted proposals). When considering the 14 eligible proposals the success rate increases to 28.6 %.

The **scope** of this first Joint Call 2013 was needs driven research on **"Sustainable and responsible supply of (non-energy) primary resources"** with the following sub-topic areas:

1. Exploration,
2. Extraction,
3. Mine closure and rehabilitation,
4. Minerals processing,
5. Metallurgy.

Nine proposals targeted more than one topic sub-area and three proposals addressed metallurgy as a second/third topic sub-area (Figure 1).

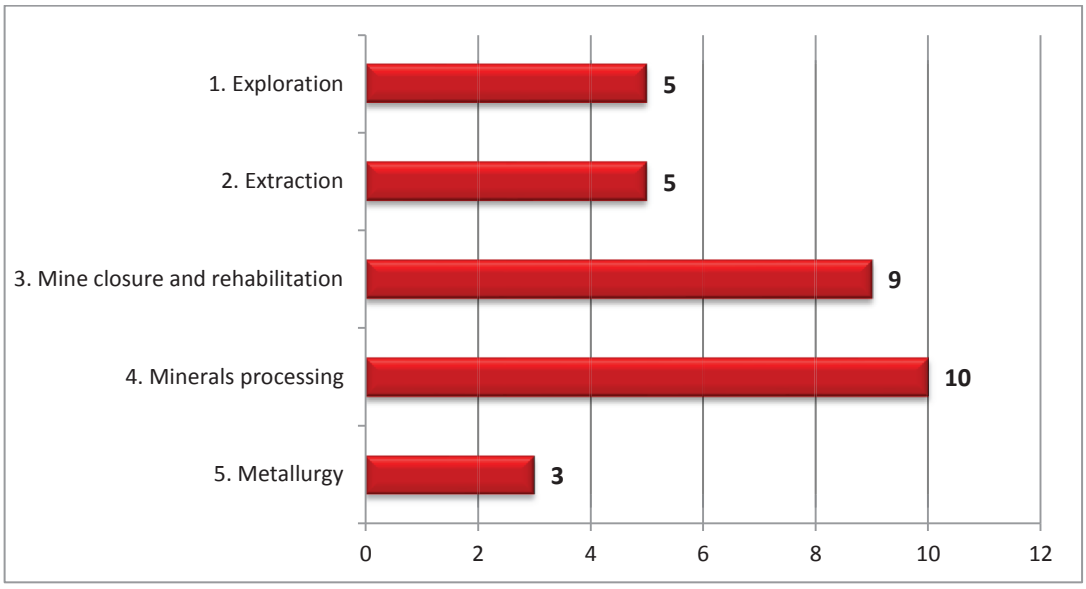


Figure 1- Distribution of the 18 submitted proposals by sub-topic areas.

In terms of country participation, there was an oversubscription rate for all countries when comparing the requested funding with the indicative committed budget, which shows a high interest in research to address material scarcity.

In terms of industrial participation, SMEs accounted for 26% of the participants in submitted projects.

The type of organization with highest participation in the 4 funded projects was higher education institutions, representing 47% (Figure 2).

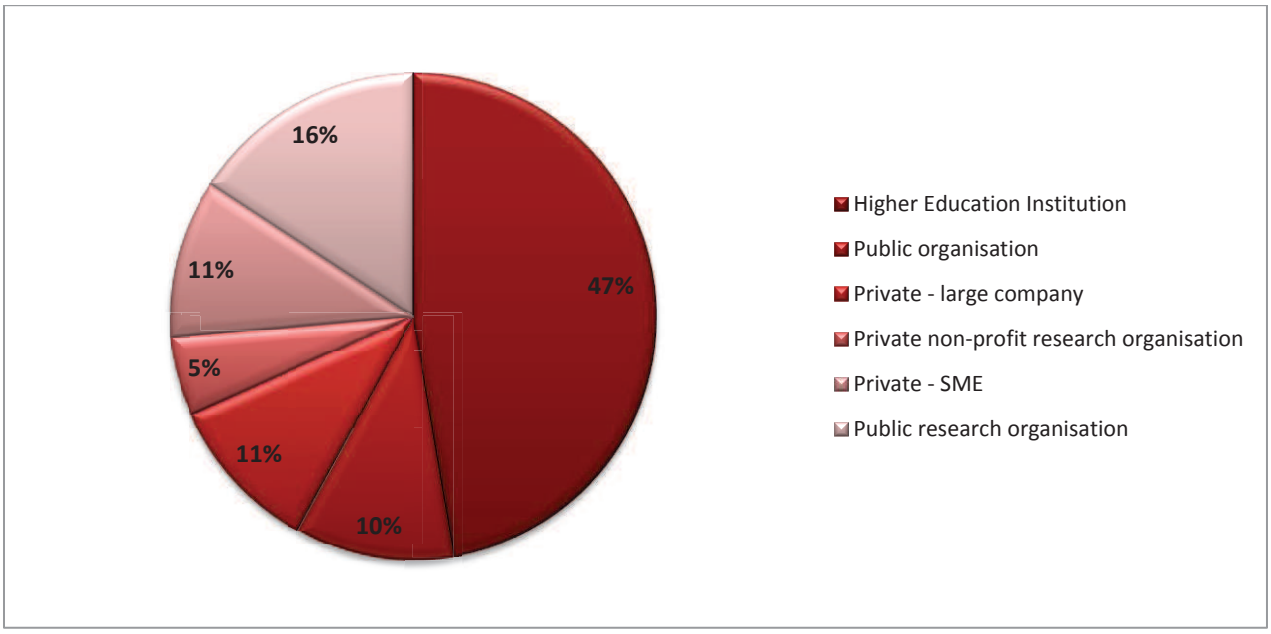


Figure 2- Distribution of types of organisations in the 4 funded projects.

In terms of country participation, all countries participating in the Joint Call funded at least two national research organisations of the funded projects (Figure 3).

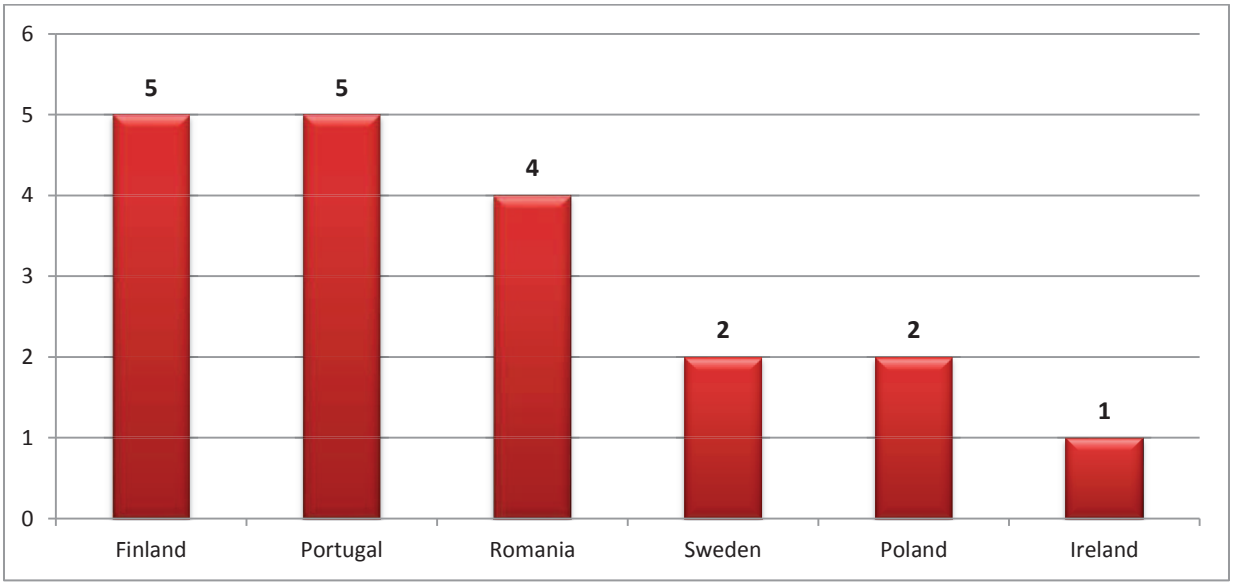


Figure 3- Geographical participation in the 4 funded projects

The 3 out of 4 funded projects involved 38 young researchers which represents the 40% of researchers participating in these projects (Figure 4).

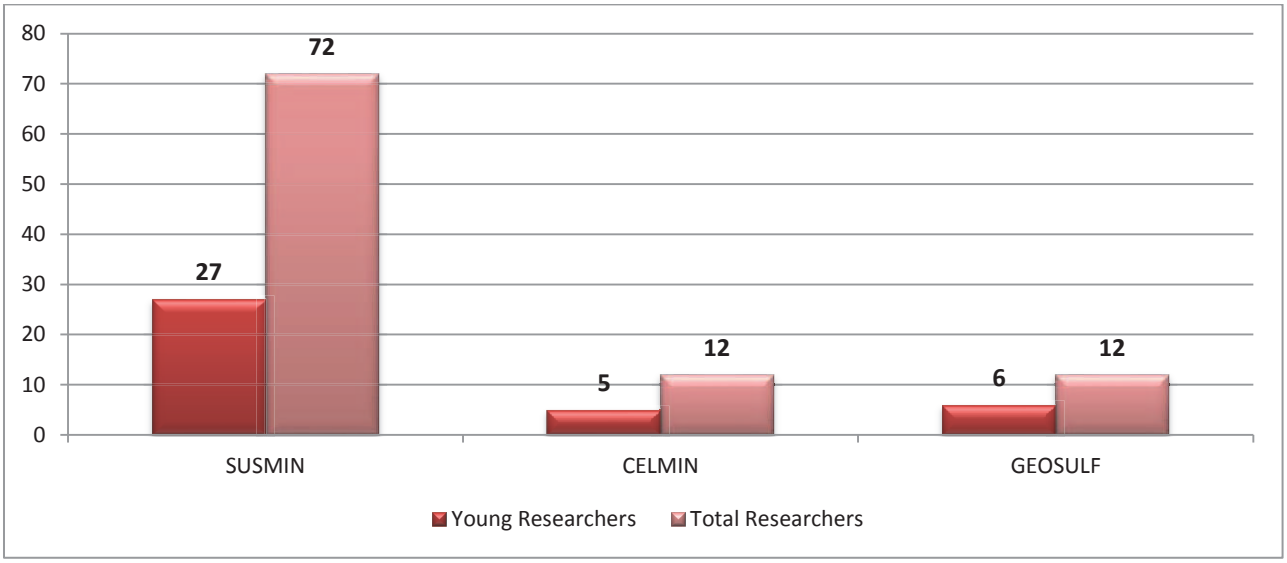


Figure 4 – Young and total researchers participating in the 4 funded projects

It is highlighted mentioned that 49% of the researchers involved in these funded projects are female which represents a good indicative of gender balance (Figure 2).

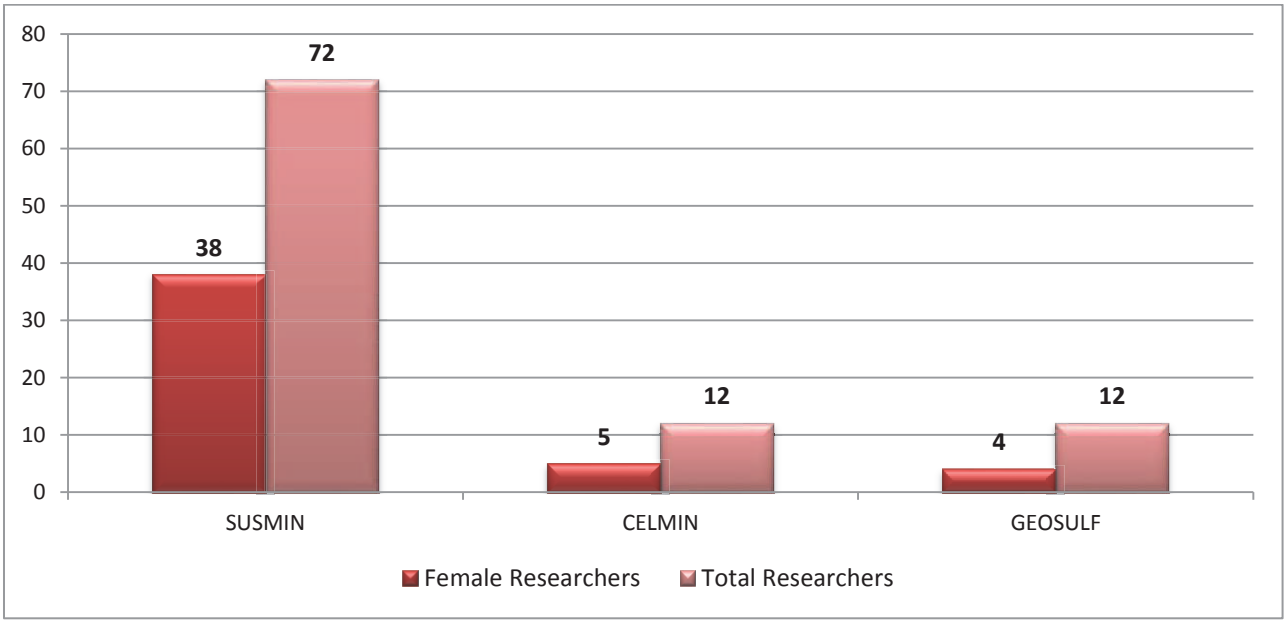


Figure 5 - Female and total researchers participating in the 4 funded projects

These projects have produced 49 publications (Annex) and 37 temporary jobs.

Through this ERA-MIN Joint Call, the funded projects will continue the collaboration with industrial partners and new industrial collaborations will be created.

Project CELMIN

Utilisation of green chemicals in non/energy extractive industries: Preparation of modified nanofibrillar celluloses (NFC) for flotation, flocculation and dewatering, and water purification in mining industry

Sub-topic: Extraction, Mine closure and rehabilitation, Minerals processing
Project Coordinator: University of Oulu (Finland)
Consortium partners:
IST Lisbon (Portugal); NUCBM (Romania); Sibelco Lda (Portugal); Sojitz Beralt Tin & Wolfram S.A. (Portugal)

Project total funding: 329.911€
Total costs: 449.911 €
Duration: 30 months (2014-2016)
Webpage

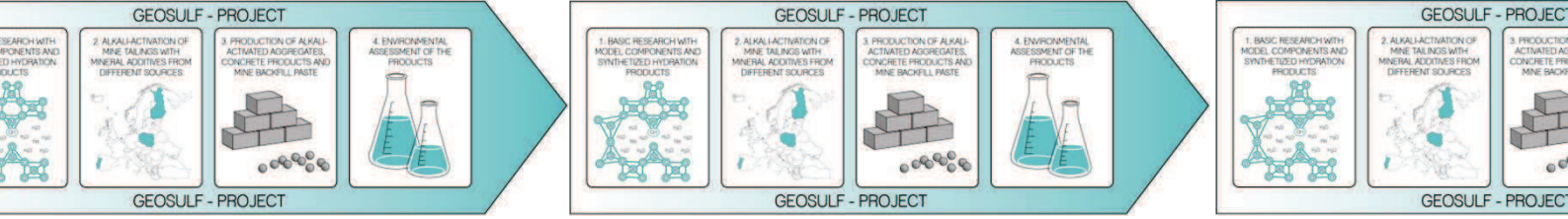
SUMMARY and RESULTS:

The progressive industrialization of almost any country worldwide increases the demand of mineral and metal resources. The high demand leads to the processing of ores possessing a high complexity of its components. Annually around 400 million metric tons of ores are crushed and ground to particles to liberate the individual minerals. Froth flotation is the main beneficiation method for the efficient separation of desired minerals from gangue materials. Oil-derived flotation reagents used, however, are potentially harmful for human beings, animals and the environment, and therefore biocompatible candidates would be needed. Nanocellulose or cellulose nanocrystals are potential agents to replace commercial flotation reagents or flocculation agents in dewatering of finely ground particles to achieve a sustainable and efficient processing of ores.

The aim of the project was to design various chemical modifications affecting the functional properties of nanocelluloses and study those nanocelluloses with respect to their function in selective flotation (collector/depressant) and flocculation of finely dispersed mineral particles. Additionally, the role of adsorption interaction of cellulose chemicals on given minerals in the performance of froth flotation was aimed to study in order to get fundamental understanding for the basis of the development of tailored nanocellulose chemicals.

Project showed that cellulose can be chemically modified and properties adjusted such a way they can be used as green chemicals in froth flotation and dewatering/flocculation of mining industry. During the project it was showed that functionalized nanocellulose collectors, depressants or flocculants have a performance similar than oil-based chemicals with lower environmental impact. Functionalization based on increased hydrophilicity with increasing anionic charge and increased amphiphilicity by attaching the amino groups with extending alkyl chain lengths were designed. The importance of the free surface charges of the nanocellulose on the adsorption behavior on minerals, as well as on the particle- bubble attachments during flotation experiments was recorded. The investigations with binary quartz-hematite and quartz-alumina systems showed that nanocelluloses can selectively interact with one mineral rendering its wetting properties to more hydrophobic and thus separate the mineral efficiently from the gangue mineral. The results also suggest that nanocellulose carboxylation and sulfonation may be a route for selective flocculation e.g. in quartz/hematite separation.

Cellulose based chemicals to have a great potential in mineral processing. The periodate oxidation of cellulose to dialdehyde cellulose and the subsequent functionalization of it were proved to be technically feasible. For commercialization, the optimization of each process step would be needed in order to clarify full economical potential. Also a novel route to produce nanocellulose chemicals by using deep eutectic solvents could be an economical and environmental sound alternative and would be a worth of research.



Project GEOSULF

Utilization of sulphide mine tailings in geopolymer materials

Sub-topic: Mine closure and rehabilitation, Minerals processing
Project Coordinator: University of Oulu (Finland)
Consortium partners:
AGH University of Science and Technology (Poland);
University of Aveiro (Portugal)

Project total funding: 601.025 €
Total costs: 781.052 €
Duration: 40 months (2014-2017)
Webpage: GEOSULF

SUMMARY and RESULTS:

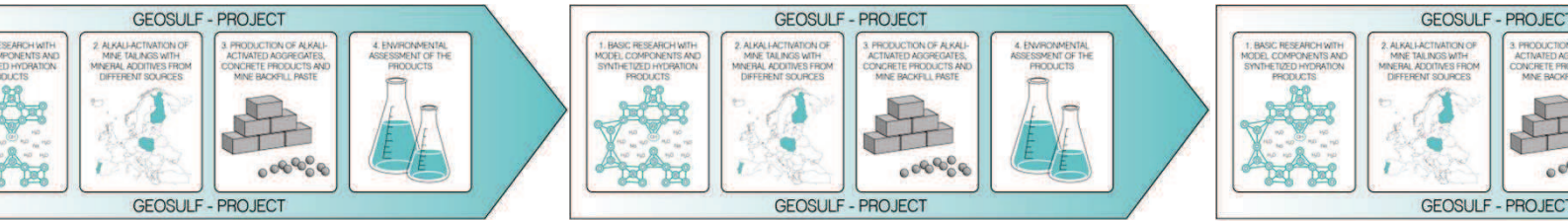
Disposal of mine tailings is one of the most important environmental issues during mine lifetime. In the EU, mining and quarrying are contributing 727 million tons waste, which is 28.3 % of the total waste amount. Some of these wastes such as sulphidic mine tailings consist of many harmful components which can cause several environmental and ecological risks because of their tendency to oxidize in the presence of water or air.

Alkali activation or geopolymerization is known to be an effective method to stabilize hazardous waste materials including the mine tailings. This aim of this project was to understand more deeply the methods how different elements can be stabilized and what are the possibilities to stabilize mine tailings with high amount of sulphates. The project involves the contribution of three different universities from Finland, Poland and Portugal in order to provide knowledge for more sustainable disposing methods for mine tailings all over the Europe.

The Finnish mine tailings studied in this work had chemical composition promising for alkali-activation. However, the reactivity of the material was low, which means that there is need for co-binder to utilize these tailings in geopolymer materials. With a proper co-binder material such as blast furnace slag or metakaolin, it was possible to achieve strength required in construction materials. The Portuguese mine tailings had low aluminosilicate content, so it was proposed to use as an aggregate rather than a reactive component.
Even though there was a possibility to achieve good mechanical properties of geopolymer based on tailings and slag, the environmental analysis shows that there was increased leaching of oxyanions such as As and V after geopolymerization. Although the stabilization of anionic species was poor, it was possible to stabilize a large amount of different cationic species into the geopolymer structure. Longer curing period improved also the immobilization of oxyanion species. The immobilization mechanism should be further examined in order to understand the role of different parameters from stabilization point of view.

It is possible to use mine tailings as geopolymer aggregates or fillers in concrete. The mine tailings were incorporated into mortar and concrete bricks either as partial aggregate replacement (sand) or in the form of lightweight aggregates previously prepared by geopolymerization of Finnish mine tailings. This introduction of mine tailings promoted obvious benefits in the fresh and hardened state of mortars and concretes. The introduction of mine tailing into a ceramic brick tile paste was also evaluated and it is a viable solution with improved final properties for this type of products. Nevertheless, the viability of this solution still requires further studies.

The project shows promising results to use of sulphidic tailings as geopolymer aggregates in mortar or concrete. The project improved significantly the current understanding on geopolymerization of mine tailings. In future, tailings with different mineralogy (e.g. silicate tailings) might be further studied since the research related to geopolymerization of mine tailings is still at very initial stage.



Project SUSMIN

Tools for sustainable gold mining in EU

Sub-topic: Minerals processing
Project Coordinator: Geological Survey of Finland (Finland)
Consortium partners:
Luleå University of Technology (Sweden);
Geological Institute of Romania (Romania); Wroclaw University of Technology (Poland); Babes-Bolyai University (Romania); University of Porto (Portugal); Trinity College Dublin (Ireland)

Project total funding: 1.227.205 €
Total costs: 1.562.454 €
Duration: 36 months (2014-2016)
Webpage: SUSMIN

SUMMARY and RESULTS:

Although the gold demand has been constantly increasing in past years, the commodity findings have been decreasing and the extraction of gold has complicated due to increasing complexity and decreasing grade of the ores. Additionally, even gold mining could increase economical development, it has also challenges in eco-efficiency and extraction methods (e.g. cyanide). Thus, the novel energy and resource-effici ent methods and technologies for mineral processing should be developed to concentrate selectively different gold bearing minerals. Furthermore, technologies for efficient treatment of mine waters, sustainable management of wastes, and methods to diminish environmental and social impacts of mining are needed. These problems were addressed by the three year long project SUSMIN.

The SUSMIN consortium led by Geological Survey of Finland (GTK) included seven research partners from six EU member states Finland, Sweden, Portugal, Romania, Poland and Ireland. Additionally nine globally on mining industry working industry partners were contributing in the SUSMIN consortium, so implementation of results from the project can be translated into direct and significant economic benefits.

The SUSMIN-project identified and evaluated environmental impacts and economical challenges of gold mining within EU. The objective of the project was to increase the transnational cooperation and to support environmentally, socially and economically sustainable viable gold production

SUSMIN project provided novel information on potential and reliable geophysical methods combination to enhance the gold exploration. Beneficiation studies provided optimized leaching parameters for gold recovery from both cyanide and alternative leaching methods (e.g. thiosulphate) as well as utility of processing aids for selective gold recovery. In addition, water treatment studies verified the effectiveness of different adsorbent materials to treat arsenic containing process effluent, dewatering and seepage waters to meet the environmental standards for mine water quality. Also factors controlling arsenic leaching from gold mine wastes in dynamic conditions were determined. The research verified applicability of environmental monitoring tools and isotopic tracers to assess contaminant migration to mine environment.

Additionally, the study provided new approach for using ecological risk assessment to improve environmental management strategies at mines. Moreover, key issues affecting social license to operate (SLO) at gold mines in EU were canvassed. This knowledge can be utilized to enhance the corporate social responsibility as well as community engagement and management of the relations with the stakeholders in gold mining areas to improve sustainability and long term development of the mining areas.

ANNEX:

- Project CELMIN:

Title	Link (doi or similar)
Flocculation of fine hematite and quartz suspensions with anionic cellulose nanofibers	10.1016/j.ces.2016.04.014
Alkyl aminated nanocelluloses in selective flotation of aluminium oxide and quartz	10.1016/j.ces.2016.01.052
Interactions between Cellulose Nanocrystals and Quartz: Adsorption and Wettability Studies	10.1016/j.colsurfa.2015.10.022
Amino-modified cellulose nanocrystals with adjustable hydrophobicity from combined regioselective oxidation and reductive amination	10.1016/j.carbpol.2015.09.089
Use of chemically modified nanocelluloses in flotation of hematite and quartz	10.1021/ie503415t
Physicochemical Properties of Aminated Butyl-Nanocrystals in Correlation to the Flotation Response of Quartz.	Accepted to IMPC 2016, Flotation: From Chemistry to Machines. Paper 719. Québec, Canada. 11th-15th September 2016.
Desenvolvimento de reagentes químicos´verdes´para flutuaçao de minerais	Indústriae Ambiente nº 86, may/june 2014. (Publindústria-EdiçõesTécnicas), nº 47 (ISSN 1645-1783)
Environmental risks of abandoning a mining project already started: Romaltyn Mining Baia Mare.	https://doi.org/10.1088/1757-899X/144/1/012004

❖ Project GEOSULF:

Title	Link (doi or similar)
Alkali activation as new option for gold mine tailings inertization	https://doi.org/10.1016/j.jclepro.2018.03.182
Utilization of sulphidic tailings from gold mine as a raw material in geopolymerization	10.1016/j.minpro.2016.02.012
Inertization of mine tailing via cold consolidation in geopolymer matrix	10.4028/www.scientific.net/KEM.761.31
Influence of sulphides on hydration of ground granulated slag alkali activated mortars and pastes	10.4028/www.scientific.net/KEM.761.92
Effect of metakaolinite on properties of alkali activated slag materials	10.4028/www.scientific.net/KEM.761.69
Influence of calcined mine tailings on the properties of alkali activated slag mortars	10.4028/www.scientific.net/KEM.761.83
Development and incorporation of lightweight waste-based geopolymer aggregates in mortar and concrete	10.1016/j.conbuildmat.2016.11.017
Mine tailings as a raw material for chemically bonded ceramics (CBC) – a review	10.1016/j.jclepro.2017.10.280

❖ Project SUSMIN:

Title	Link (doi or similar)
The use of low binder proportions in cemented paste backfill: Effects on As-leaching	Hamberg, Glenn, Maurice, Alakangas. Minerals Engineering 2015. Vol. 78. pp. 74-82. http://dx.doi.org/10.1016/j.mineng.2015.04.017
Treatment of arsenic-rich waters using granular iron hydroxides	Małgorzata Szlachta, Patryk Wójtowicz. Proceedings of 14th International Conference on Environmental Science and Technology, 2015; ISBN 978-960-7475-52-7
Treatment of arsenic-rich waters using granular iron hydroxides	Małgorzata Szlachta, Patryk Wójtowicz. Desalination and Water Treatment, 2016, vol. 57, no. 54, pp. 26376-26381
Sustainable treatment solution for arsenic-rich water from gold mines	Małgorzata Szlachta, Patryk Wójtowicz, Marzena Kozielec, Paweł Włodarczyk. Chapter in "Current issues in water treatment and water distribution"; Silesian University of Technology Press, 2016, pp. 93-99; ISBN 978-83-934758-5-8
Removal of arsenic (III) and arsenic (V) from water using material based on natural minerals	Małgorzata Szlachta, Patryk Wójtowicz. Proceedings "Arsenic Research and Global Sustainability, series Arsenic in the Environment"; CRC Press, 2016, pp. 480-481; ISSN 2154-6568
Adsorptive removal of arsenic species from aqueous solutions using granular ferric hydroxide (paper in Polish)	Małgorzata Szlachta, Patryk Wójtowicz. Ochrona Środowiska (Environmental Pollution Control), 2016, vol. 38, no. 4, pp. 47-52
Ferric hydroxide-based media for removal of toxic arsenic species: Kinetic, equilibrium and thermodynamic studies (paper in press)	Małgorzata Szlachta, Patryk Wójtowicz. Environmental Protection Engineering, 2018
Characterization of selected conservative and non-conservative isotopes in mine effluent and impacted surface waters: Implications for tracer applications at the mine-site scale	Larkins, C., Turunen, K., Mänttäri, I., Lahaye, Hendrikson, N., Forsman, P., Backnäs, S. Applied Geochemistry Vol. 91. pp 1-13. 2018. (In press) DOI: 10.17632/c5wk6nn4mp.1
Analyzing Contaminant Mixing and Dilution in Stream Waters influenced by Mine Water Discharges	Räsänen, T., Turunen, K., Hämäläinen, E., Hämäläinen, M., Backnäs S. 2018. Environmental Monitoring and Assessment 2018. (In Review)
Release of arsenic from cyanidation tailings	Hamberg, Glenn, Maurice, Alakangas. 2016. Minerals engineering. Vol. 93. pp 57-64. http://dx.doi.org/10.1016/j.mineng.2016.04.013

Lowering the water saturation level in cemented paste backfill mixtures – effect on the release of arsenic	R. Hamberg, C. Maurice, L. Alakangas. 2017. Minerals engineering. Vol 112. pp 84-91. https://doi.org/10.1016/j.mineng.2017.05.005
In-situ technologies for groundwater treatment: the case of arsenic	Marta I. Litter, José Luis Cortina, António M.A. Fiúza, Aurora Futuro & Christos Tsakiroglou. 2014. 208pp. In-Situ Remediation of Arsenic-Contaminated Sites, Chapter 1. ISBN 9780415620857
Arsenic Sorption by Iron Based Sorbents (IBS)	Fiuza, A., Futuro, A., Guimaraes, M. 2014. Chapter in Book: Book, One Century of the Discovery of Arsenicosis in Latin America (1914-2014). https://books.google.fi/books?isbn=1315778882
Arsenic removal using "green" Nano Zero Valent Iron	Fiuza, A., Futuro, A., De Lurdes, M., Vila, C., Rios, R. 2016. Chapter in Book: Arsenic Research and Global Sustainability DOI: 10.1201/b20466-233
Bromine leaching as an alternative method for gold dissolution	Rui Sousa, Aurora Futuro, António Fiúza, M.C. Vila, M.L. Dinis. 2018. Minerals Engineering. Vol 118, 16-23 pp. https://doi.org/10.1016/j.mineng.2017.12.019
Thiosulfate Leaching of the Auriferous Ore from Castromil Deposit – A Case Study	Rui Sousa, Aurora Futuro, António Fiúza. 2016. International Journal of Geological and Environmental Engineering. Vol 10. no3. http://scholar.waset.org/1999.6/10004104
Co-Disposal of Coal Ash with Mine Tailings in Surface Paste Disposal Practices: A Gold Mining Case Study	M. L. Dinis, M. C. Vila, A. Fiúza, A. Futuro, C. Nunes. 2016. International Journal of Geological and Environmental Engineering. Vol 10. no 7. https://waset.org/publications/10004915/co-disposal-of-coal-ash-with-mine-tailings-in-surface-paste-disposal-practices-a-gold-mining-case-study
Supergene gold enrichment in the Castromil-Serra da Quinta gold deposit	C. Cruz, F. Noronha, P. Santos , J.K. Mortensen and A. Lima. 2018. Mineralogical magazine. pp. 1-33. https://doi.org/10.1180/minmag.2017.081.063
Geophysics in gold exploration: some applications to northern Portugal gold deposits.	S. LEAL, R. MOURA, A. LIMA, A. PIVTORAK, D. RODRIGUES. SGEM2017 Conference Proceedings. Vol. 17, Issue 14, 147-156 pp. DOI: 0.5593/sgem2017/14/S05.019
Petrography and composition of white micas in the gold-	Cruz, C., Ribeiro, M.A., Noronha, F., Lima,

bearing system of Serra da Quinta (Paredes-Sobreira, Northern Portugal)	A. 2016. Comunicações Geológicas (2015) 102, Especial I, 23-26
Exploratory Leaching Tests of a Gold Ore	Carina Vicente 2014, Master in Mining and Geo-Environmental Engineering, FEUP
Alternative Reagents To Cyanide In Gold Leaching – A Case Study: Application Of The Ammoniacal- Thiosulphate System On Castromil Ores	Joana Silva Duerte 2015, Master in Mining and Geo-Environmental Engineering, FEUP
Conception of a system for treating gold ores by heap Leaching	Didacio Salema 2015, Master in Mining and Geo-Environmental Engineering, FEUP
Paste Co-deposition of gold ore tailings with incorporation of coal ashes	Carina Nunes 2015, Master in Mining and Geo-Environmental Engineering, FEUP
Sustainable strategies for tailings management of a gold mine project	Alejandra Lopez Sanchez 2015, Master in Mining and Geo-Environmental Engineering, FEUP
Waste management in the scope of a gold mine project - prediction of acid drainage and study of mitigation solutions	Antonio Fernandez 2016, Master in Mining and Geo-Environmental Engineering, FEUP
Mapping hydrothermal gold mineralization using Landsat 8 data. A case of study in Chaves license, Portugal.	Rui Frutuoso 2014, Geology FCUP
Gold mineralizations in Ponte da Barca licence	Filipe Valente 2015, Geology FCUP
Análise Espacial das Mineralizações de Antimónio em Relação com Magmatismo Básico Filoniano e Outras Características Geológicas no Distrito Auri - Antimonífero Dúrico - Beirão	Adriana Silva 2016, Geology FCUP
Propriedades Magnéticas relacionadas com as alterações hidrotermais associadas a mineralizações de Au intragraníticas	Ana Gonçalves 2016, Geology FCUP
Supporting water management strategies in gold mining using ecological risk assessment.	Malinen, M. 2015. http://urn.fi/urn:nbn:fi:uef-20160263
Effects of the Treated Drainage and Process Water in the Water System below the Kittilä Mine.	Hämäläinen, M. 2015. Savonia University of Applied Sciences. (In Finnish) http://www.theseus.fi/handle/10024/96331
Impact of Water Balance and Flow Profile on Mixing and Diluting Substances in the Recipient River of Kittilä Mine.	Hämäläinen, E. 2015. Savonia University of Applied Sciences. (In Finnish) https://www.theseus.fi/handle/10024/91769

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TO FOSTER CIRCULAR ECONOMY

ERA-MIN Joint Call 2014 Results:

Summary Reports

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Joint Call 2014 results: Summary Reports

Thirteen ERA-MIN funding agencies, **ADEME (France), ANR (France), DST (South Africa), FCT (Portugal), MINCYT (Argentina), MINECO (Spain), NCBR (Poland), OTKA (Hungary), SGU (Sweden), TEKES (Finland), TUBITAK (Turkey), UEFISCDI (Romania) and VINNOVA (Sweden),** committed together a total of €7.87 million of national/regional public funds to support their national/regional participants in the selected transnational R&D proposals submitted to the **second ERA-MIN Joint Call 2014.**

21 full proposals were submitted in total from 83 participants. Out of the 21 proposals, 16 passed the eligibility check. After evaluation and ranking, 7 transnational projects, involving 38 organisations, were finally selected for funding: project acronyms **AMDREY, BOFLUX, ENVIREE, EXTRAVAN, NewOres, RAREASH and StartGeoDelineation**. The total project funding was €5.43 million, being the total costs of €8.57 million. The total success rate of the Joint Call 2014 was 33,3% (7 funded/21 submitted proposals). When considering the 16 eligible proposals the success rate increases to 43,75 %.

The **scope** of this second Joint Call 2014 was needs driven research on **"Sustainable Supply of Raw Materials in Europe"** with the following main topic areas:

1. Primary resources,
2. Secondary resources (recycling),
3. Substitution of critical materials.

The sub-topics "Extraction" and "Recycling of mining and smelting residues" are covered in 4 out of 7 funded projects (Figure 1).

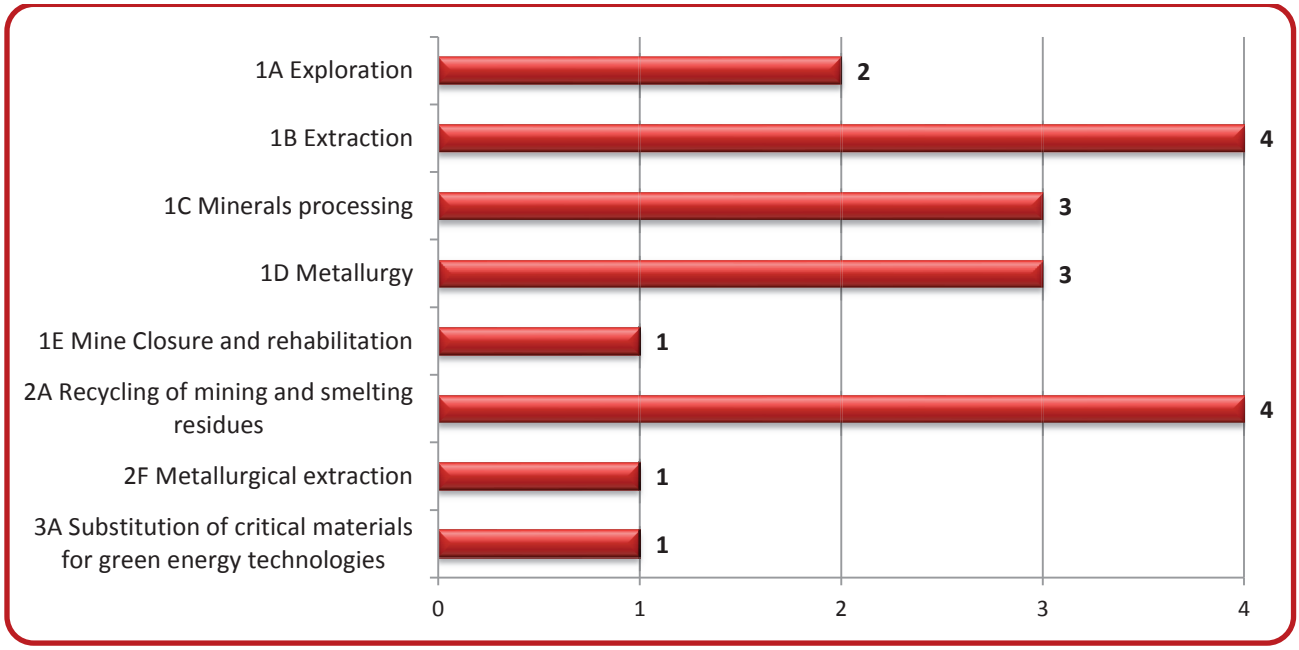


Figure 1 - Distribution of sub-topics addressed in the 7 funded projects.

The type of organisation with the highest participation in the 7 funded projects was public research organisation, representing 34%, followed by higher education institution with a participation of 32% (Figure 2).

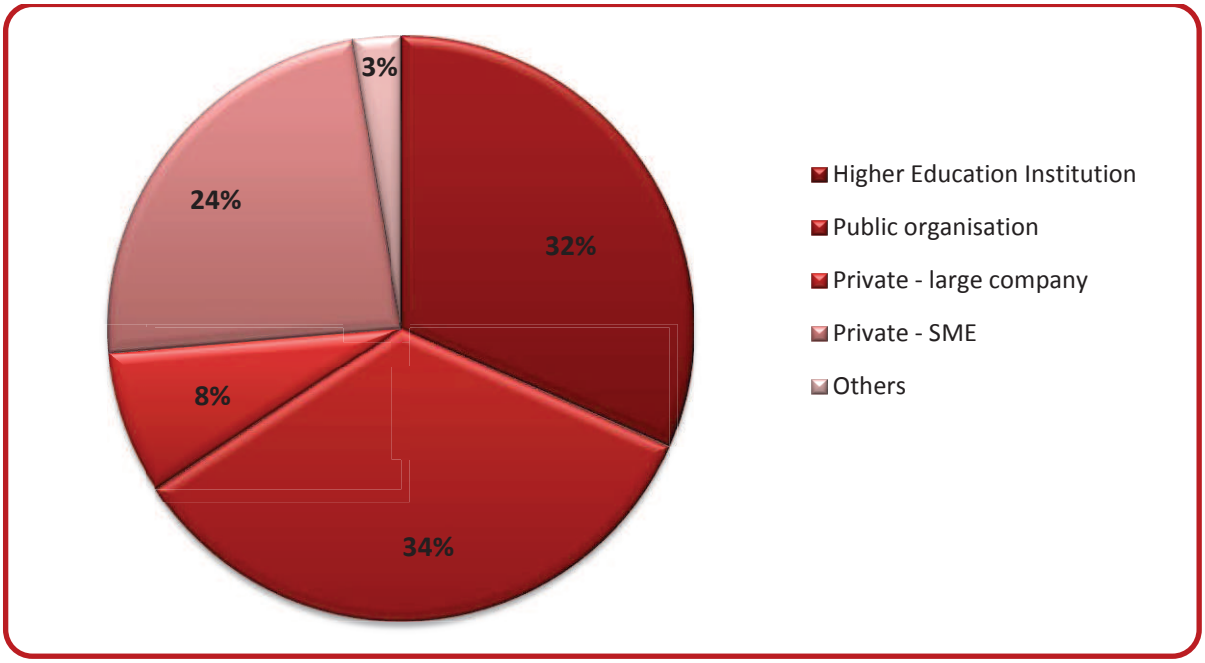


Figure 2 - Distribution of types of organisations in the 7 funded projects.

In terms of country participation, 8 out of 11 countries participating in this Joint Call funded at least two national/regional organisations of the funded projects (Figure 3).

Figure 3 - Geographical participation in the 7 funded projects.

All funded projects involved 69 young researchers which represents the 36% of researchers participating in these projects (Figure 4).

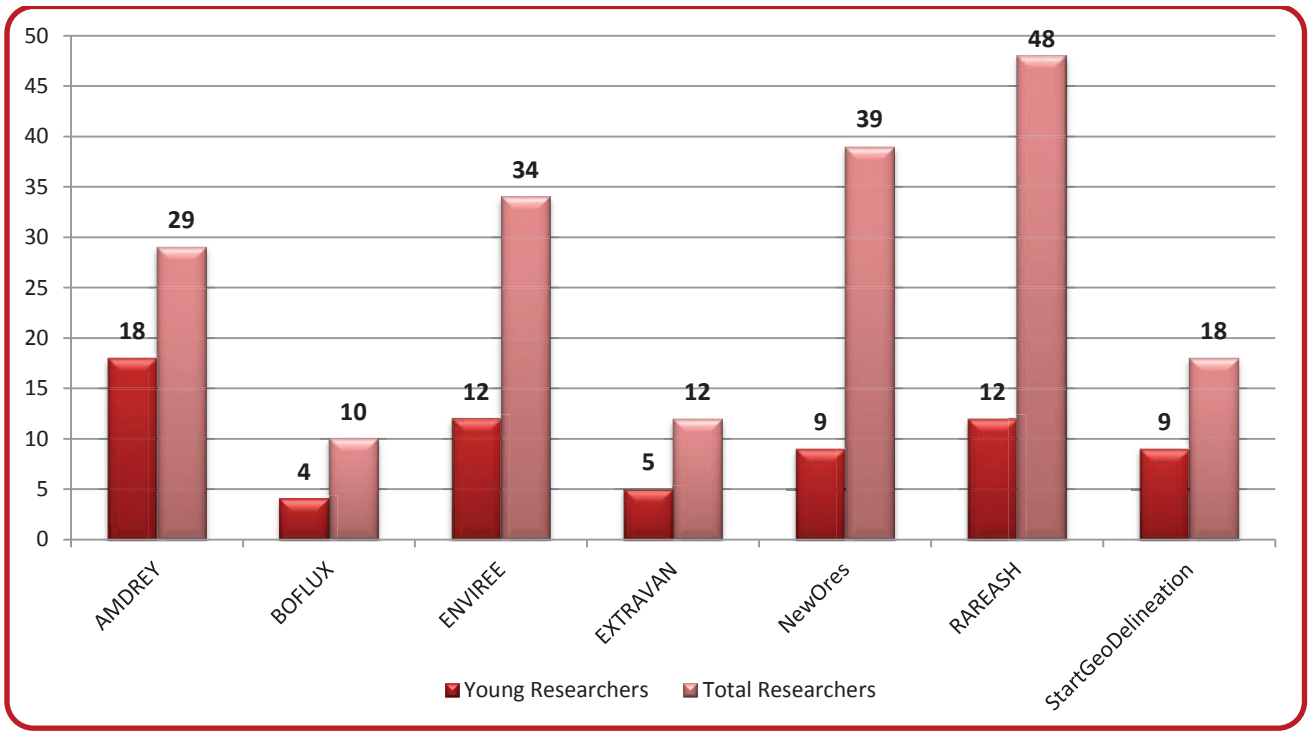


Figure 4 – Young and total researchers participating in the 7 funded projects.

It is highlighted mentioned that 44% of the researchers involved in these funded projects are female which represents a good indicative of gender balance (Figure 5).

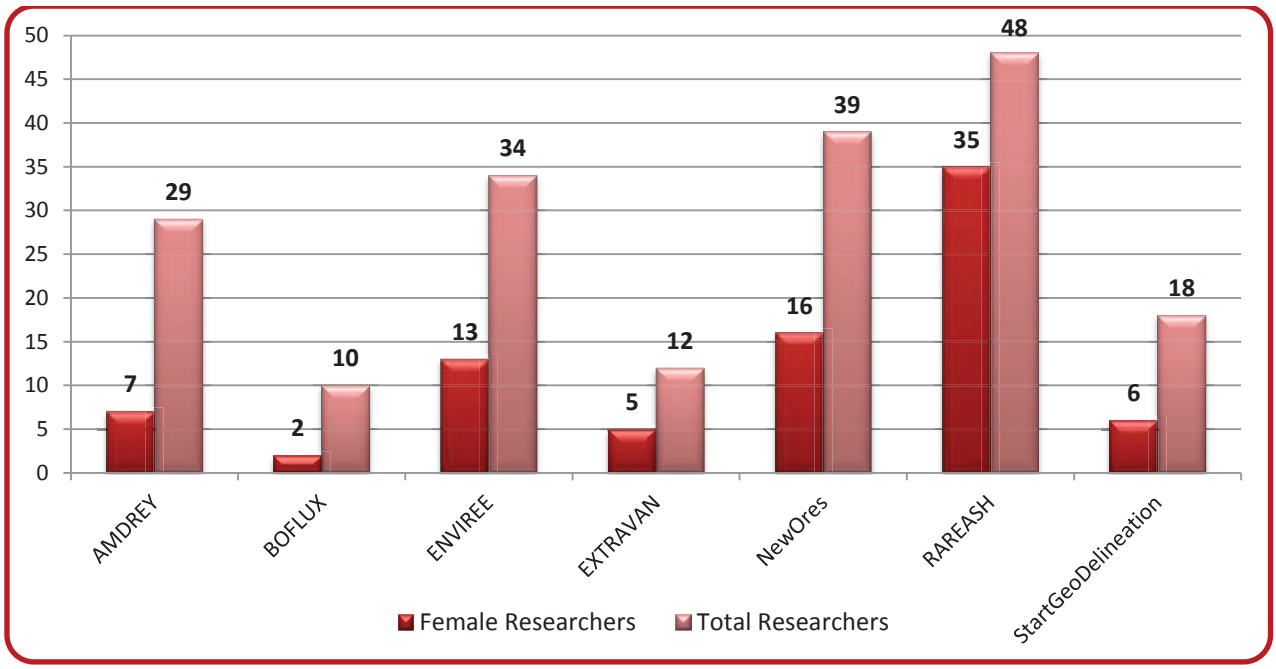


Figure 5 - Female and total researchers participating in the 7 funded projects.

These projects have produced 79 publications (Annex I), 5 patents/licenses and 1 start-up (Annex II) as well as created 17 permanent jobs and 63 temporary jobs.

New industrial collaborations have been created through the funded projects and the continuation of these collaborations have been strengthened, being very important the role developed by the industrial sector in the funded projects. Underline the creation of the Ferrovan start-up.

Project AMDREY

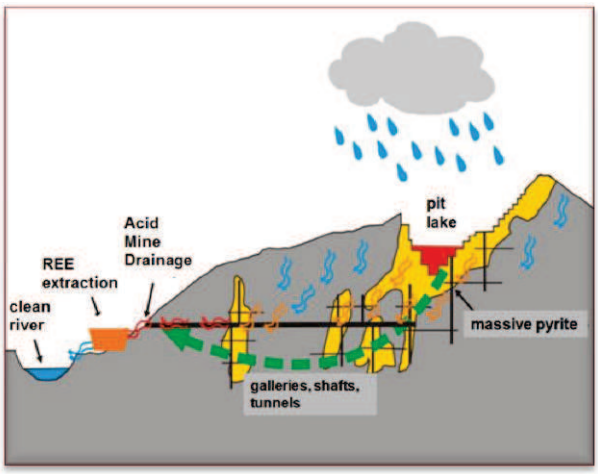
Extraction of Rare Earth Elements from Acid Mine Drainage

Sub-topic: Recycling of mining and smelting residues (incl. historical dumps and tailings)
Project Coordinator: CSIC (Spain)
Consortium partners:
Oy Chemec Ab (Finland); ICSM (France); UFS (South Africa); UHU (Spain).

Project total funding: 830.140 €
Project total costs: 972.500 €
Duration: 24 months (2016-2018)

SUMMARY and RESULTS:

Acid Mine Drainage (AMD) is commonly considered an environmental pollution issue. However, Rare Earth Elements (Scandium, Yttrium and Lanthanides) concentrations in AMD can be several orders of magnitude higher than in naturally occurring water bodies. With respect to shale standards, the REY distribution pattern in AMD is convex and enriched in intermediate and valuable REY. Traditional AMD remediation systems are based on the reaction of AMD with a base, such as lime or limestone, generating a large amount of iron and aluminum-rich sludge. The main objective of the AMDREY project was to characterize and recover REE from the treatment sludge and thereafter investigate the efficiency of some chemical separation techniques.



A main outcome of AMDREY project is to link the 100% recovering of REE in the sludge of AMD treatment. Thus, in active neutralization plants with lime or sodium carbonate, precipitation of the iron oxyhydroxide schwertmannite occurs at pH below 4 with no REE scavenge. On the contrary, the equivalent aluminum mineral basaluminite precipitates as neutralization progresses to pH 6.5. Practically all REE are retained in basaluminite. The same behavior is observed in passive remediation systems consisting of AMD circulating through a permeable substrate of limestone. There, schwertmannite and basaluminite successive fronts precipitate as the AMD is neutralized by calcite. The accumulation of REE in the treatment wastes is especially relevant in the Phalaborwa Industrial Complex (PIC) in South Africa. There, the waste rock dumps are composed mainly of carbonatite-material, with high REE content. Therefore, this alkaline material becomes an attractive solution to not only neutralize the acid drainage, but also to enrich them in REE. The results of AMDREY have demonstrated that commercial calcite, commonly used in treatment systems can be replaced by carbonatite (mining by-product), which will decrease costs dramatically.

Further studies need to be performed in order to characterize the REE-enriched wastes and its feasibility as a marketable product. Two chemical separation processes have been evaluated based on different technological systems based on “green chemistry” rules. Liquid/liquid extraction using solvating agent such as TODGA is efficient to recover selectively REE (Nd=Y>Gd>La >> Fe, Al, Mg, Ca) but the main drawback is the need to increase the concentration of H_2SO_4 until 7.5M. With respect solid-liquid systems with no solvent, one of the synthesized resin seems to be an efficient candidate to the treatment of AMD with high extraction (>90%) and stripping (>80%) behavior. First attempts to biorecovery have also been tested by means of investigating the metal resistant mechanisms of two bacteria. *Clostridium sp.* was able to reduce and accumulate Eu^{2+} intracellularly, whereas *Thermus scotoductus* SA-01 accumulated Eu extracellularly using two different strategies. The results have significant implications for REE biorecovery, probably as nanoparticles for *Clostridium sp*. and as insoluble carbonates for *T. scotoductus* SA-01. Rather than extracting REE from wastes, another objective of AMDREY was to extract REE straightforward from the AMD. Thus, the work led by Chemec Oy used the vegetal-based adsorber CH Collector to remove scandium from AMD. A pilot plant mounted in the Tharsis area (SW Spain) removed up to 81% Sc from the acidic waters without any pH control.

The main constraint of recovering REE from AMD is the low annual tonnage of the ore. Compiling all the acid drainage produced in an entire region, such as the Iberian Pyrite Belt, a total annual reserve of 70 to 100 t REY_2O_3, with an average rate of 0.23% REY_2O_3 is obtained. The rate is in the lower range of those compiled for currently working mines and prospects. The annual reserves are less than 0.05% of the world annual production. However, despite the low rates and annual production expected for the IPB, the natural processes that generate AMD are expected to continue for centuries or thousands of years. In this sense, the IPB could function as a giant heap leaching process of regional scale, in which rain and oxygen act as natural driving forces with no energy investment. Furthermore, as the main objective of AMD treatment is to remove acidity and pollutants, the benefits for water reserves and ecosystems are obvious. Therefore, recovery from AMD can be considered a small but environmentally friendly and renewable source of REE.

Project BOFLUX

Characterisation of the impact, boron addition has on the physical and smelting properties of chromite slag

Sub-topic: Metallurgy
Project Coordinator: Mintek (South Africa)
Consortium partners:
Ab Etiproducts Oy (Finland);
Siyanda Chrome Smelting Company Pty Ltd (South Africa)

Project total funding: 221.925 €
Project total costs: 269.500 €
Duration: 24 months (2015-2017)
Website:
http://www.mintek.co.za/technical-divisions/pyrometallurgy-pdd/boflux/

SUMMARY and RESULTS:

BOFLUX, funded via ERA-MIN, is a joint project between Mintek, EtiProducts, and Siyanda Chrome Company which aimed to explore the potential benefits of using colemanite as an alternative fluxing agent for chromite smelting. This report is presents at a high level the main outcomes and conclusions of the work.

Laboratory-scale smelting tests were conducted at Mintek over the course of two years. The work included evaluation of a variety of boron-containing materials to replace or partly replace conventional fluxes. The laboratory test results indicated that colemanite had the best outcomes. The tests confirmed that addition of boron lowers the liquidus of the slag and smelting can be done at 1650°C, lower than conventional smelting temperatures. The grade of the final product improved by approximately 1 to 2.5 % Cr units, depending on the grade of the ore smelted. The test work was supplemented by modelling work through which various flowsheets were developed and evaluated for suitability. The study focused on South African chromite concentrates, assessing the impact of using various grades of colemanite, analyses and samples provided by EtiProducts.

EtiProducts can supply a wide range of grades and part of the objective was to establish whether any significant benefits can be demonstrated for a one type of colemanite over any other.

The main conclusions from the study can be summarised as follows:

- No significant benefits were demonstrated between the various types of colemanite ores which EtiProducts can supply. Colemanite products that would be suitable for chromite smelting of South African chromite ores would need at least 30% B_2O_3 and 25% CaO with a maximum SiO_2 content of 8% (on an uncalcined basis). Most products in the EtiProducts range meet these requirements.
- Replacing conventional fluxes with colemanite appears to offer an opportunity for process intensification (increased chrome production for the same power input). The benefits are marginal for smelting process without pre-treatment of the colemanite (calcining). Pre-heating of the ore and colemanite is thus highly recommended.
- Tests with lower grade chromite concentrates resulted in only marginal metallurgical improvements. Modelling work and mass and energy balance calculations showed the same trends as the test work. Benefits are most significant South African metallurgical grade chromite.
- The flowsheet scenario with the most potential for process intensification includes provision for pre-heating feed and calcination of colemanite; here the benefits when compared to conventional processing is significantly higher than any other scenario evaluated. Pre-heating of chromite ore is not a direct benefit of BOFLUX. The benefits presented by addition of colemanite must always be weighed against the cost of replacing conventional fluxes with colemanite. The BOFLUX results highlighted that the cost of the colemanite will need to be similar to that of conventional fluxes.
- Some of the BOFLUX benefits may not be directly measurable through a test work based study that focused on the metallurgical impact. However, it is worth highlighting that lower operating temperatures can lead to increased longevity of refractories and tap-holes, which can improve cost and efficiency of a commercial smelter significantly. Reduction of maintenance downtime, even relatively small reductions, could outweigh any process intensification benefits associated with the increased throughput for example. This may ultimately be the primary selling point for colemanite, especially for chromite smelter that is currently operating with smelting temperature in excess of 1800°C

The BOFLUX project demonstrated successfully that process intensification appears to be possible by replacing conventional fluxes (quartzite and/or limestone) with colemanite, however further technoeconomic and sensitivity studies should be undertaken to evaluate the cost of replacing conventional fluxes with an imported product.

The technical outcomes of the work conducted under the BOFLUX project added to the scientific knowledge and directly resulted in additional research beyond the original scope of the project.

Project ENVIREE

ENVIronmentally friendly and efficient methods for extraction of Rare Earth Elements from secondary sources

Sub-topic: Extraction, Minerals processing, Mine closure and rehabilitation, Recycling of mining and smelting residues (incl. historical dumps and tailings)

Project Coordinator: Chalmers (Sweden)

Consortium partners:
BRGM (France); CEA (France); KIT (Germany); PIPAS (Norway); AGH UST (Poland); R.O.T. (Poland); EDM (Portugal); IST-ID (Portugal); AICU (Romania); CGS (South Africa)

Project total funding: 1.822.371 €
Project total costs: 2.481.175 €
Duration: 40 months (2015-2018)
Webpage: www.enviree.eu

SUMMARY and RESULTS:

The ENVIREE project aimed at strengthening the REE supply within Europe by addressing exploitation of specific secondary sources. The purpose was to study innovative approaches in processing (beneficiation, leaching and separation) of identified materials and to provide economic and environmental assessment of the tested methods. ENVIREE was a highly multidisciplinary project with competences ranging from analysis techniques using e.g. Mössbauer to the more visual knowledge-based mineralogy in the field, and in size from molecule level to ton scale. This wide scope made the initial work challenging when several disciplines, each with their own science language were to agree on what to do and how. In addition to these more technical works there was also an extensive training and education activity.

Large sampling scheme implemented within ENVIREE did lead to a very useful information on REE content of different mine wastes in different countries and although only three samples were selected for further treatment the analysis of the remaining ones can serve as a basis for further research and potential exploitation depending on REE prices and demand in the future. The base for the analysis was that the samples were grinded and homogenised before the actual analysis was made using neutron activation analysis, X-ray fluorescence and inducted coupled plasma mass spectrometry analysis. The most REE rich residue was the one from New Kankberg in Sweden with about 500 ppm REE content. For the selected samples from Portugal and Sweden efficient beneficiation techniques were developed and applied proving that the REE content in the ultimately treated material could be increased by orders of magnitude thus increasing the potential market efficiency of the following selective separation scheme. The basic techniques used here were gravimetry for the Portuguese samples increasing the concentration from 52 to 284 ppm and flotation techniques for New Kankberg increasing this content to more than 5000 ppm. Not surprisingly the dominating REE were lanthanum, cerium and neodymium.

For the separation CYANEX based systems were used for e.g. the New Kankberg beneficiated samples. This was tested in lab scale and a small pilot test was run. The DGA based systems did not show enough promise for further development. Also some complete novel ligands were tested successfully but due to limited supply not used for upscaling. Other techniques such as hollow fibres and ionic liquids were tested in smaller scale with promising results but not developed further to pilot plant scale. All in all the separation schemes developed clearly showed the technical feasibility of the techniques adopted in ENVIREE.

To further show the potential profitability for both environment and economy, studies and environmental analyses were made for selected processing scenarios making it possible to guide future prospectors in this field. It was clear that even for the very rich samples from New Kankberg there were clear benefits to treat the material at the same place as the original mining activities for energy conservation. For the reclamation of the mining sites it was shown that the remaining material for the New Kankberg material could be stored on the surface and used as a soil substrate in land reclamation. The situation for the more sulphur-rich residue from the Covas site there was a need for neutralisation processes before the material could be used for reclamation purposes, which gives a negative impact for the overall, holistic system evaluation.

Last but not least the training and education work within ENVIREE has been highly successful with practical field trips combined with theoretical courses in all the scientific areas included. This gave the participating younger scientists a unique possibility to broaden their competence and thus lay the foundations for a more holistic approach to not only mine waste use but also to potential use in primary material recovery.

Project EXTRAVAN

Innovative extraction and management of vanadium from high vanadium iron concentrate and steel slags

Sub-topic: Extraction, Minerals processing, Metallurgy, Recycling of mining and smelting residues (incl. historical dumps and tailings), Metallurgical extraction

Project Coordinator: MEFOS (Sweden)

Consortium partners: FERROVAN (Finland); BRGM (France)

Project total funding: 829.912 €

Project total costs: 1.203.234 €

Duration: 26 months (2014-2017)

SUMMARY and RESULTS:

The EXTRAVAN aimed at developing novel technologies for production of vanadium in Europe based on V-bearing iron ore and V-bearing steel slag existing in the Nordic countries. EXTRAVAN focused on two major technological approaches. Route A is a "roasting-leaching" route including a novel approach for roasting of V-slag with very high vanadium content. This technology has been developed and demonstrated during the EXTRAVAN project. The industrial partner has contributed additional 35 000 € to make this pilot testing possible. The vanadium yield achieved is as high as 97%. All technical steps from high V-slag to roasting, leaching, AVP precipitation, V2O3 and V2O5 preparation, FeV making have been demonstrated in various scale with a very high overall vanadium yield. The results of the project have been an important and crucial part of the project development of MKOY (FERROVAN). The second focus (Route B) in the EXTRAVAN was development of a new approach for vanadium extraction using spent PVC waste stream as the chlorination agent. BRGM has demonstrated the concept capability in laboratory scale. High process flexibility has been demonstrated and a high V-recovery yield has been achieved.

The technological achievements include a special roasting approach for high V-containing slag for the FERROVAN process aiming for a high overall vanadium recovery yield demonstrated in large pilot scale and a carbo-chlorination approach using spent PVC waste demonstrated in laboratory scale.

The scientific achievements include:

- A PhD thesis work (Mikael Lindvall, Swerim/Royal Institute of Technology (KTH), Sweden).
- A Master thesis work (Martin Berg, KTH).
- Two publications concerning "roasting-leaching" and optimized conditions for vanadium extraction (published).
- Two publications on the PVC roasting approach (to be submitted by BRGM).
- Over 10 presentations at various international conferences, seminars and workshops including those arranged by ERAMIN (Stockholm/Berlin).

The main conclusions are as follows:

- The technical feasibility of the whole chain of Route A – "reduction – selective oxidation – roasting – leaching/precipitation – FeV making" has been completely demonstrated.
- The roasting, leaching, vanadate and V2O5/V2O3 preparation and FeV-making steps are successfully developed and proved in this project including a novel high temperature roasting (HTR) process has been developed. The innovation will shorten the roasting time by a factor of about 10. The vanadium recovery yield of the HTR roasted V-slag was up to 97%.
- A novel oxy-chlorination process for direct roasting of high V-bearing BOF steel slag has also been demonstrated in laboratory scale with an overall vanadium recovery of up to 95%. In this process Cl-bearing wastes like PVC waste streams could used as the energy source and reagent. Further verification of this concept in larger scale is needed and recommended.

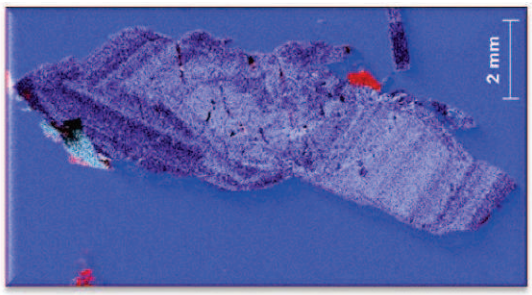
Project NewOres

Development of New models for the genesis of Rare Metal (W, Nb, Ta, Li) Ore deposits from the European Variscan Belt and valorization of low grade and fine grained ore and mine tailings

Sub-topic: Exploration, Extraction, Minerals processing, Metallurgy
Project Coordinator: GeoRessources-CNRS-Université de Lorraine (France)
Consortium partners:
Université d'Orléans (France); FCUP (Portugal); FFCUL (Portugal); LNEG (Portugal); Sojitz Beralt Tin & Wolfram S.A. (Portugal)

Project total funding: 451.343 €
Project total costs: 1.818.244 €
Duration: 48 months (2015-2018)

SUMMARY and RESULTS:



A new vision of the W-Sn, Nb-Ta concentration processes for better industrial choices in exploration, exploitation and ore processing: NewOreS is a project devoted to the development of new models of ore deposition relevant to the W-Sn (Nb-Ta-Li) mineralisations, and intends to propose new exploration guides for this type of mineralization, by building i) a fully comprehensive model for the behaviour of metals duringcrustalmagmatic events, and ii) by understanding the behaviour of these metals at the hydrothermal stage, and the factors controlling metal deposition thanks to a more precise reconstruction of the pressure-temperature evolution.

One of the major targets was Panasqueira which represents the largest W deposit in Europe linked to a series of granite intrusions. One of the main goal was the development of exploratory mapping of particular mineral chemistry features aiming at the assessment of possible compositional zonings that may provide clues about the superposition of ore-forming processes (eventually controlled by distinct sources and structures). The results gathered show that: (1) the western and eastern sectors of the mine display contrasting features recognised at different scales and impacting both the metallogenic model for the Panasqueira system and the ongoing short range exploration surveys. On the basis of the relative abundance of various mineral phases (namely, coarse-grained muscovite, topaz, tourmaline, cassiterite and wolframite), the influence of at least two distinct metal sources may be inferred, both recording a similar geochemical evolution: the early stages of mineral infillings in the western sectors suggest the prevalence of B F(±P)-rich fluids, while in the eastern sectors the fluids involved in these initial stages would have been more enriched in F(±P±B). Accordingly, cassiterite (along with topaz) is much more abundant in the western sectors of the mine, as the exploitation works carried out in the last years have also shown. A third different source of fluids and metals, possibly centred at Vale de Ermida (to the NW), can be glimpsed if differences in the relative abundance of Bi, As, Sb (and Ag) mineral phases are considered.

Ore genesis: from field studies and in situ metal analysis in minerals to conceptual and numerical modelling. From province to magmatic body and fault scale, methodology consisted in coupling: i) field studies with systematic analyses of ore mineralogy and relative chronology, as well as trace elements in ore minerals, ii) paleofluid studies with precise reconstruction of pressure-temperature-fluid composition evolution, iv) dating of the main fluid events, fluid flow reconstruction based on mineral textures, followed by mass and heat transfer modelling. The targets are various parts of the Hercynian chain, especially i) NW Massif Central (France) with representative examples of rare-metal enriched granite bodies, and pegmatites mineralized in Sn-W-Li-Nb-Ta deposits (Puy-les-Vignes and St Sylvestre pegmatites) and ii) Iberia (Portugal) with the Argemela granite, and the Panasqueira deposit (Portugal). A mineralogical and numerical modelling approach to interpret the geometry and constrain the fluid circulations (directions, velocity) in the deposit has been applied to Panasqueira. At Argemela, the structural and geophysical constraints have shown that the intrusion is a pipe-like body. The mechanisms of the magmatic-hydrothermal transition have been characterized and illustrate as a rare example of deposition of Mn-rich wolframite deposited from magmatic fluids. A new ore deposit model is set up for Panasqueira deposit. Contrary to most recent interpretations, the deposit appears to be a focus of fluid flow and large convection cells implying metamorphic fluids and little evidence of true magmatic fluids probably mixed and/or buffered quickly by the host rocks. The overall system is linked to a major and deep zone of partial melting and successive magmatic pulses are necessary to explain the huge complexity and duration of the W-Sn (Nb-Ta) ores, in association with exhumation of the belt and subsequent changes in fluid pressure , and the amounts of other brought metals (Cu, Zn). Same conclusions concern French Massif Central.

Ore processing and mine tailings: The processing of low grade and fine-grained ores has been attempted for the recovery of copper from tailings from already mined deposits, in particular from Panasqueira, but appears rather difficult due to the ore oxidation after storing in waste piles. Thus, the processing of low grade and fine-grained ores and tailings from Panasqueira wastes has been attempted for the copper by flotation, but Cu exploitation from mine tailings remains difficult. Besides successive upgrading of eluvial Sn ores have been obtained successfully on the Bejanca ores.

Project RAREASH

Assessment of Possible Recycling Directions of Heavy & Rare Metals Discovered from Combustion Waste Products

Sub-topic: Recycling of mining and smelting residues (incl. historical dumps and tailings), Substitution of critical materials for green energy technologies

Project Coordinator: CPMTE/UPB (Romania)

Consortium partners:

ADW (Poland); GIG (Poland); LIPOR (Portugal); UP (Portugal); CEO (Romania); UCB (Romania)

Project total funding: 805.327 €

Project total costs: 859.803 €

Duration: 44 months (2015-2018)

Website: http://upb-cpmte.ro/rareash-project/

SUMMARY and RESULTS:

The project aimed to demonstrate by a detailed fundamental and applied investigation the technically feasible alternative for strategic metals production as Heavy and Rare Metals (HRM) consisting of Lanthanides and Gallium, Strontium, Rubidium, Yttrium and Wolfram by utilizing fresh and reuse landfilled fly ash and bottom ash as a source soft (pulverized) rock.

The proposed approach, with a very limited experience in Europe and even worldwide, demonstrated innovative methods/technologies to develop metal recovery processes and transform wastes into high-grade and valuable metals with various applications, creating the possibility for a fast and low-cost access to strategic metals and a widespread saving of EU primary mineral resources.

The project achieved results will be used as an initial basis for the advanced, waste-less and environmentally safety utilization of various ashes to obtain concentrates, high purity reactives, metals and metallic salts, and adsorbents, metal and oxide nanoparticles, scale controlled and functionalized as well as solar collectors precursors potential manufacturing to be used in high-tech and environmental purposes.

The characterization of Oltenia bottom ash, Polish coal ashes and LIPOR ashes was one of the main aims of the project together with the metals extraction. In this sense the characterization tasks were fully accomplished and a much better insight on the characteristic of theses ashes towards their use as a secondary source of rare and heavy metals is an achievement of the project. Resuming:

(i) it was found that Oltenia bottom ash is a potentially promising source of REY. However, Gd seems to be the most promising element, especially in the 0.090–0.125mm and < 0.063mm size fractions;

(ii) it was found that for Polish samples the prospect for recovery are four elements (cerium, lanthanum, scandium, neodymium), which account for a total of 77% of the total rare earth elements contained in the examined waste. Coefficients of variation of these elements are in the range of 6% to 11%. The average content of such rare earth elements as scandium, lanthanum, cerium, praseodymium, neodymium, and dysprosium is higher than in the earth's crust.

(iii) in LIPOR fly ash between 75% and 85% of the samples mass is concentrated in the >75 µm size fractions, and the <25 µm fraction is always less than 2%. The insoluble residue corresponds to approximately a 20% of the fly ash and does not vary with time. The chemical analysis of this fraction shows that its major compounds are chlorides, sulfates and CaO. However, Pb value was also high (783 ppm).

The LIPOR bottom ash size fraction < 2mm shows high concentration of Mo, Cu, Pb, Zn, Cd, Sb, In, Zr, and Sn in relation to the Upper Continental Crust, whereas the fly ash shows high concentrations of Mo, Cu, Pb, Zn, Cd, Sb, W, In, Bi, Zr, Sn, and Se in relation to the Upper Continental Crust. Meanwhile, major, minor and trace elements do not present high variations with time.

Derivative scientific objectives:

The Oltenia bottom ash not used for metals extraction has a promising potential to be recycled in making ceramic composites.

It was found that in coal fly ash and bottom ash from Romania and Poland, several morphotypes did not fit into the general fly ash classifications, unless grouped together as “undifferentiated inorganics”. However, many of these morphotypes not only have distinctive petrographic patterns but are also characterized by a chemical assemblage dominated by Ca, Mg, and P. Therefore, the following nomenclature are proposed: “calcispheres”, “calcimagnesiaspheres” and “magnesiaspheres”.

Project StartGeoDelineation

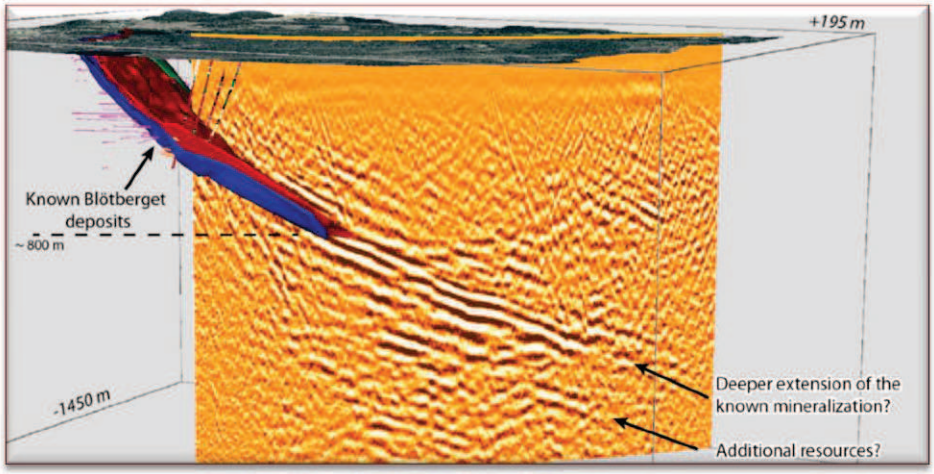
State-of-the-art geophysical and geological methods for delineation of mineral deposits and their associated structures

Sub-topic: Exploration, Extraction
Project Coordinator: UU (Sweden)
Consortium partners:
YARA (Finland); NIO (Sweden)

Project total funding: 471.707 €
Project total costs: 963.522 €
Duration: 43 months (2014-2018)

SUMMARY and RESULTS:

StartGeoDelineation project officially started in the beginning of December 2014 and ended in May 2018. The project approaches were tested in two geologically different environments: Siilinjärvi alkaline-carbonatite deposit in Finland and Blötberget iron-oxide deposit in Sweden. Two PhD students were employed and 3 MSc-BSc theses were produced. A number of short-term researchers worked in the project along with the senior scientists and explorationists from the partner companies. All these contributed to the acquisition of new data, revisiting existing data and new knowledge on the geology of the sites and ways to explore in a systematic manner cost-effectively. The project covered all aspects involved in mineral exploration ranging from data compilation and historical data gathering, rock physical property measurements (both laboratory and downhole), mineralogical and petrological studies to geochemistry and systematic geophysical surveys. Innovative solutions were also experimented in the project. In the Siilinjärvi, the focus was to mainly test the capability of landstreamer seismics for open-pit mine surveying and better understating of dyke emplacement through combination with magnetic property measurements and sample geochemistry. In Blötberget, depth extension, deep targeting and emplacement of the deposits were focused. New ways of geophysical data acquisitions for the first time attempted including landstreamer seismics for deep-targeting and UAV-based methods for higher-resolution targeting iron-oxide deposits. Over dozen of peer-reviewed high-quality journal publications and tens of conference abstracts were produced ensuring the efficient dissemination of the new knowledge from the project. StartGeoDelineation took part in all organized events by the sponsors and presented the work in progress. The successes of the project and the great network resulted in collaboration among the partners for a H2020 project, Smart Exploration, where StartGeoDelineation continuity is guaranteed for another three years.



ANNEX I:

❖ Project AMDREY:

Title	Link (doi or similar)
Recovery of Rare Earth Elements and Yttrium from Passive-Remediation Systems of Acid Mine Drainage.	Environmental Science & Technology, 50: 8255-8262, 2016
A geochemical approach to the restoration plans for the Odiel River basin (SW Spain), a watershed deeply polluted by acid mine drainage.	Environmental Science and Pollution Research, 24: 4506-4516, 2017
Quantification of proportions of different water sources in a mining operation.	The Science of the total environment, 619-620: 587-599 , 2017
The nanocrystalline structure of basaluminite, an aluminum hydroxide sulfate from acid mine drainage	American Mineralogist, 102: 2381-2389, 2018
Application of nanofiltration for recovery of rare earth elements from acidic waters: influence of transition elements, acidity and membrane stability.	Desalination, 430:33-44. 2018
Passive elimination of sulfate and metals from acid mine drainage using combined limestone and barium carbonate systems.	Journal of Cleaner Production 182, DOI: 10.1016/j.jclepro.2018.01.224
Geochemical behavior of trace elements in acid mine drainage controlled by basaluminite precipitation.	2nd European Mineralogical Conference, Rimini, Italy, September, 2016
REE Mineralogy of wastes from acid mine drainage treatment.	2nd European Mineralogical Conference, Rimini, Italy, September, 2016
Extraction of rare earth elements from acid mine drainage	2nd European Mineralogical Conference, Rimini, Italy, September, 2016
REE Scavening from Acid Mine Drainage By Basaluminite: preliminary studies.	ESRF User Meeting 2017. Grenoble, February, 2017
Acid mine drainage: a small but sustainable source of rare earth elements	2nd Conference on European Rare Earth Resources, Santorini, Greece, May, 2017
REE accumulation in residues from acid mine water treatment.	2nd Conference on European Rare Earth Resources, Santorini, Greece, May, 2017
Remediation of Highly Polluted AMD by passive technologies.	13th International Mine Water Association Congress, Lappeeranta, Finland, June 2017
Acid Mine Drainage, a possible source of Rare Earth Elements.	13th International Mine Water Association Congress, Lappeeranta, Finland, June 2017
Potencial económico de los drenajes ácidos de la Faja Pirítica Ibérica.	XXXVI Reunión de la Sociedad Española de Mineralogía , Oviedo
Rare Earth Element Adsorption onto Basaluminite	XXXVI Reunión de la Sociedad Española de Mineralogía , Oviedo
Rare Earth Elements retention onto basaluminite: understanding sorption mechanisms.	Goldschdmidt Conference, Paris, August 2017
Geochemistry of REE in Acid Mine Drainage: sorption onto basaluminite and schwertmannite.	American Geological Association Meeting, New Orleans, December 2017
Is basaluminite a mineral?	XXXVII Reunión de la Sociedad Española de Mineralogía , Madrid, Junio 2018
Partition of Scandium, Yttrium and Rare Earth Elements between Acid Mine Drainage and its evaporitic sulfates. Preliminary results	XXXVII Reunión de la Sociedad Española de Mineralogía , Madrid, Junio 2018
Acid Mine Drainage in the Iberian Pyrite Belt: geochemistry, passive remediation and valorization of wastes	Keynote in Symposium on Mines and Environment -2018 Rouyn-Noranda, Canada, June 2018
Lights and shades of passive remediation systems in the	Course on AMD Remediation Systems

Iberian Pyrite Belt	Symposium on Mines and Environment -2018 Rouyn-Noranda, Canada, June 2018
Use of alkaline mine waste as treatment for acid drainage.	Proceedings ISBN 978-3-86012-533-5 Drebenstedt, Carsten, Paul, Michael (eds).
Novel strategy to concentrate rare earth elements by neutralization of acid drainage from phosphogypsum stacks using carbonatites	ERES2017: 2nd European Rare Earth Resources Conference|Santorini|2017
New reductive interactions of REY by Thermus Scotoductus SA-01 and Clostridium sp.	ERES2017: 2nd European Rare Earth Resources Conference|Santorini|2017
Neutralization of Acid Drainage and Concentration of Rare Earth Elements Using Carbonatites; Results from a Bench Scale Experiment.	Proceedings: "ISBN 978-0-620-80650-3. Wolkersdorfer, Ch.; Sartz, L.; Weber, A.; Burgess, J.; Tremblay, G. (eds).
Biomineralization and bioaccumulation of europium by a thermophilic metal resistant bacterium	doi: 10.3389/fmicb.2019.00081

❖ Project BOFLUX:

Title	Link (doi or similar)
Fluxing of South African chromite ore with colemanite	M.W. Erwee; I.J. Geldenhuys; M.B. Sitefane; M. Masipa http://www.mintek.co.za/Pyromet/Files/2018Erwee-InfaconXV-SAIMM.pdf http://dx.doi.org/10.17159/2411-9717/2018/v118n6a15
Solid-state Reduction of South African Manganese and Chromite Ores: Effect of an organic binder and B2O3 – Solid-state Reduction of South African Manganese and Chromite Ores: Effect of an organic binder and B2O3	Herman Lagendijk, Kabwika Bisaka, Markus Erwee, Olive Makwarela IMPC 2016: XXVIII International Mineral Processing Congress Proceedings – ISBN: 978-1-926872-29-2

❖ Project ENVIREE:

Title	Link (doi or similar)
Możliwości pozyskiwania metali ziem rzadkich z odpadów poflotacyjnych i górniczych [In:] W kierunku gospodarki o obiegu zamkniętym - perspektywa przemysłu. (Eng.: Possibilities of acquiring rare earth metals from post-flotation and mining waste. Towards a circular economy - an industry perspective).	Kossakowska K., Grzesik K., Bieda B., Kozakiewicz R., 2017, Wydawnictwo IGSMiE PAN 2017. pp. 49–61. http://konferencja-pan.pl/wp-content/uploads/2017/04/monografia.pdf

❖ Project EXTRAVAN:

Title	Link (doi or similar)
The Effect of Al2O3, CaO and SiO2 on the Phase Relationship in FeO-SiO2 Based Slag with 20Mass% Vanadium	J. Sustain. Metall. DOI 10.1007/s40831-016-0088-y Published online: 16 September 2016 M. Lindvall, M.Berg, Du Sichen
Vanadium Extraction from Fe-V (2.0 Mass%)- P(0.1 Mass%) Melt and Investigation of the Phase Relations in the Formed FeO-SiO-Based with 20 Mass %V	J. Sustain. Metall. DOI 10.1007/s40831-017-0147-z Published online: 16 November 2017 M. Lindvall, J. Tikka, M.Berg, G. Ye& D. Sichen

❖ Project NewOres

Title	Link (doi or similar)
Michaud and Pichavant (2019) The H/F ratio as an indicator of contrasted wolframite deposition mechanisms	Doi: 10.1016/j.oregeorev.2018.10.015
Launay et al 2018 Deciphering fluid flow at the magmatic-hydrothermal transition: A case study from the world-class Panasqueira W–Sn–(Cu) ore deposit (Portugal).	Doi : 10.1016/j.epsl.2018.07.012
Carocci et al. : Rutile from Panasqueira (central Portugal): an Excellent Pathfinder for Tungsten Deposition	Doi: 10.3390/min9010009
Goncalves et al.: Using multifractal modelling, singularity mapping, and geochemical indexes for targeting buried mineralization: application to the W-Sn Panasqueira ore-system	Doi: 10.1016/j.gexplo.2017.07.008
Bobos et. al. Fe-, Fe,Mn- and Fe,Mg-chlorite: A genetic linkage to W, (Cu,Mo) - mineralization in the magmatic-hydrothermal system of Borralha, Northern Portugal. M ineralogical Magazine 189: 42-53	Doi:10.1180/minmag.2017.081.104

❖ Project RAREASH

Title	Link (doi or similar)
Assessment of landfilled Oltenia lignite bottom ash (Romania) as a source of rare earth elements.	International Journal of Coal Geology 201 (2019) 109–126 B. Valentim, A.T. Abagiu, L. Anghelescu, D. Flores, D. French, P. Gonçalves, A. Guedes, L.G. Popescu, G. Predeanu, J. Ribeiro, V. Slăvescu, C.R. Ward.
Spinels in the fly ash of power plant ostroleka (poland)	18th International Multidisciplinary Scientific GeoConference SGEM 2018, Vienna, 1-8 A. KLUPA, Z.ADAMCZYK
Petrographic and SEM/EDS characterization of bottom ash fractions obtained using magnetic separation equipment.	WSEAS TRANSACTIONS on ENVIRONMENT and DEVELOPMENT, Volume 14, London 26-28 october, 2018, 526-530, E-ISSN: 2224-3496 526. B.VALENTIM, P. GONÇALVES, A. GUEDES, L.G. POPESCU, G. PREDEANU.
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Capitalization of industrial wastes in economic circuit – a way to reduction the impact upon environment due to its storage	Fiability & Durability, "Academica Brâncuşi", Târgu Jiu, No 1/ 2018, 327-332. ISSN 1844 – 640X. L. G. Popescu, F. Grofu.
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Combustion waste landfill sites as alternative sources of rare earth elements	Scientific Conference SGEM Vienna Green 2017, Vol.17/43, 51-58 B. BIAŁECKA, M. CEMPA, J. CAŁUS-MOSZKO
Assessment of landfilled Oltenia lignite bottom ash (Romania) as a source of rare earth elements.	ICCP Program & Abstract Book. 69th Annual Meeting of the International Committee for Coal and Organic Petrology, September 3-9. 2017, Bucharest, Romania. Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften Heft 92, 145-147. ISBN 978-3-510-49239-8. B. Valentim, A.T. Abagiu, L. Anghelescu, D. Flores, D. French, P. Gonçalves, A. Guedes, L.G. Popescu, G. Predeanu, J. Ribeiro, V. Slăvescu, C.R. Ward
Extraction of heavy and rare earth metals from bottom ash: a kinetic study of the acid attack	ICCP Program & Abstract Book. 69th Annual Meeting of the International Committee for Coal and Organic Petrology, September 3-9.

	2017, Bucharest, Romania. Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften Heft 92, 114-116. ISBN 978-3-510-49239-8. C. Onose, M. Mihaly, E.A. Rogozea, G. Predeanu, B. Valentim, A. Guedes, D. Cadar, N.L. Olteanu, A. Meghea
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An overview of the RAREASH project (Assessment of possible recycling directions of heavy & rare metals recovered from combustion waste products)	JORNADAS DO ICT, 26-27 June 2017, Universidade do Minho, Braga, Portugal, 25. A. Gonçalves, G. Predeanu, B. Bialecka, L.G. Popescu, B. Valentim, A.T. Abagiu, L. Anghelescu, D. Flores, J. Ribeiro, V. Slavescu, A. Guedes, J. Moszko.
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Eco-friendly extraction of heavy and rare earth metals from combustion waste products - the kinetic study of the acid attack.	ICCP Program & Abstract Book. 67th Annual Meeting of the International Committee for Coal and Organic Petrology. Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften Heft 87, 129-130. ISBN 978-3-510-49236-7. Onose C., Tane A., Mihaly M., Stamate D., Stamate, Popa D., A., Rogozea A.
Coal ashes a potential secondary raw material for the recovery of heavy & rare metals.	ICCP Program & Abstract Book. 67th Annual Meeting of the International Committee for Coal and Organic Petrology. Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften Heft 87, 135-136. ISBN 978-3-510-49236-7. Predeanu G., Popescu L.G., Abagiu T.A., Valentim B., Guedes A., Bialecka B., Moszko J.
Project's Brochure	www.upb-cpmte.ro/rareash-proiect/

❖ StartGeoDelineation

Title	Link (doi or similar)
Anisotropy of magnetic susceptibility (AMS) in the Siilinjärvi carbonatite complex, eastern Finland	EGU2017, Vienna-Austria. Almqvist, B., Karell, F., Högdahl, K., Malehmir, A., Heino, P., and Salo, A., 2017
Magnetic characterization of magnetite and hematite from the Blötberget apatite-iron-oxide deposits (Bergslagen), central Sweden.	Canadian Journal of Earth Sciences, in press. https://doi.org/10.1139/cjes-2018-0183 Almqvist, B., Bjork, A., Mattsson, H., Hedlund, D., Gunnarsson, K., Malehmir, A., Högdahl, K., Bäckström, E., and Marsden, P., 2018.
Magnetic properties for characterization and quantification of magnetite and hematite in apatite iron-oxide deposits at Blötberget, central Sweden.	Nordic Geological Winter Meeting, Helsinki, Finland. Björk, A., Almqvist, B.S.G., Setter, M., Högdahl, K., Malehmir, A., 2016.
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Pros and cons of 2D vs 3D seismic mineral exploration surveys.	First Break, 35(8), 49–55. http://earthdoc.eage.org/publication/publicationdetails/?publication=89805 Malehmir, A., Bellefleur, G., Koivisto, E., and Juhlin, C., 2017
The potential of rotary-wing UAV-based magnetic surveys for mineral exploration: A case study from central Sweden.	The Leading Edge, 36(7), 552–557. https://doi.org/10.1190/tle36070552.1 Malehmir, A., Dynesius, L., Paulusson, K., Paulusson, A., Johansson, H., Bastani, M., Wedmark, M., and Marsden, P., 2017.
Landstreamer seismics and physical property measurements in the Siilinjärvi open-pit apatite (phosphate) mine, central Finland.	Geophysics, 82, B29–B48. https://doi.org/10.1190/geo2016-0443.1 Malehmir, A., Heinonen, S., Dehgahnnejad, M., Heino, P., Maries, G., Karell, F., Suikkanen, M., and Salo, A., 2017.
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Reflection seismic imaging of iron-oxide deposits: an example from Bergslagen mining district of Sweden.	Near Surface Geoscience, Malmö-Sweden, September 2017. DOI: 10.3997/2214-4609.201702092 Maries, G., Malehmir, A., Bäckström, E.,

	Schön, M., and Marsden, P., 2017.
Downhole physical property logging for iron-oxide exploration, rock quality, and mining: An example from central Sweden.	Ore Geology Reviews, 90, 1–13. https://doi.org/10.1016/j.oregeorev.2017.10.012 Maries, G., Malehmir, A., Bäckström, E., Schön, M., and Marsden, P., 2017.
Downhole Physical Properties Measurements Supporting Iron-oxide Deep Exploration and Mining in Blötberget, Sweden.	Near Surface Geoscience, Barcelona-Spain, September 2016. DOI: 10.3997/2214-4609.201602092 Maries, G., Malehmir, A., Bäckström, E., 2016.
Deep targeting iron-oxide mineralization using reflection seismic method: A case study from the Ludvika Mines of Sweden.	EAGE Near Surface Geoscience, Porto-Portugal, September 2018. Markovic, M., Maries, G., Malehmir, A., Bäckström, E., Schön, M., Jakobsson, J., and Marsden, P., 2018.
Using super-virtual first arrivals in controlled-source hardrock seismic imaging—well worth the effort.	Geophysical Journal International, 206, 716–730. https://doi.org/10.1093/gji/ggw176 Place, J.A.P., and Malehmir, A., 2016.
Gravity and magnetic survey, modeling and interpretation in the Blötberget iron-oxide mining area of central Sweden.	SEG Annual Meeting, Anaheim, California, USA. https://library.seg.org/doi/10.1190/segam2018-2992225.1 Yehuwalashet, E., and Malehmir, A., 2018.

ANNEX II:

Funded project	Title	Reference
AMDREY Patent	Procedimiento para la depuración de aguas contaminadas por metales, e instalación correspondiente	ES2534806, Universidad de Huelva-CSIC, 2016.
AMDREY Patent	Procedimiento de obtención de un recurso renovable de metales a partir de aguas ácidas de mina, e instalación correspondiente	ES2550526, Universidad de Huelva-CSIC, 2016.
EXTRAVAN Start-up	Ferrovan	www.ferrovan.com
RAREASH Patent	Odzysk metali ziem rzadkich z popiołów (Recovery of rare earth elements from ashes)	L.G. Popescu, G. Predeanu, J. Ribeiro, V. Slăvescu, C.R. Ward. Patent P.423021, 2017
StartGeoDelineation MSc thesis	Petrografisk och mineralogisk karakterisering av metadiabaser i Siilinjärvi.	Matias Carlsson (2017). Thesis 37001, Åbo Akademi.
StartGeoDelineation MSc thesis	Characterizing magnetic susceptibility and remanent magnetization of magnetite and hematite rich drill-core samples at Blötberget.	Andreas Bjork (2017). MSc thesis published in Diva, Uppsala University.
StartGeoDelineation MSc thesis	Gravity and Magnetic Survey, Modelling and Interpretation in the Blötberget Iron-Oxide Mining Area, Bergslagen, Sweden.	Ezra Yehuwalashet (2016). MSc thesis published in Diva, Uppsala University

E R A•M I N 2

RESEARCH & INNOVATION PROGRAMME ON RAW MATERIALS
TO FOSTER CIRCULAR ECONOMY

ERA-MIN Joint Call 2015 Results:

Summary Reports

Table of Content

Joint Call 2015 results: Summary Reports

Thirteen ERA-MIN funding agencies, **ADEME (France), ANR (France), DST (South Africa), FCT (Portugal), MINCYT (Argentina), MINECO (Spain), NCBR (Poland), OTKA (Hungary), SGU (Sweden), TEKES (Finland), TUBITAK (Turkey), UEFISCDI (Romania) and VINNOVA (Sweden),** committed together a total of €8 million of national/regional public funds to support their national/regional participants in the selected transnational R&D proposals submitted to the **third ERA-MIN Joint Call 2015.**

23 out of 27 full proposals were submitted in a complete form and involved a total of 124 participants. 20 passed the eligibility check. After evaluation and ranking, 6 transnational projects, involving 38 organisations, were finally selected for funding: project acronyms **BATRE-ARES, BIOCriticalMetals, CHARPHITE, COGITO-MIN, HITEM, REMinE**. The total project funding was €5.1 million, being the total costs of €6.04 million. The total success rate of the Joint Call 2015 was 26% (6 funded/23 submitted proposals).

The **scope** of this third Joint Call 2015 was needs driven research on **"Sustainable Supply of Raw Materials in Europe"** with the following main topic areas:

1. Primary resources,
2. Secondary resources (recycling),
3. Substitution of critical materials.

The sub-topics "Extraction", "Mine Closure and rehabilitation" and "Exploration" are the most addressed (*Figure 1*).

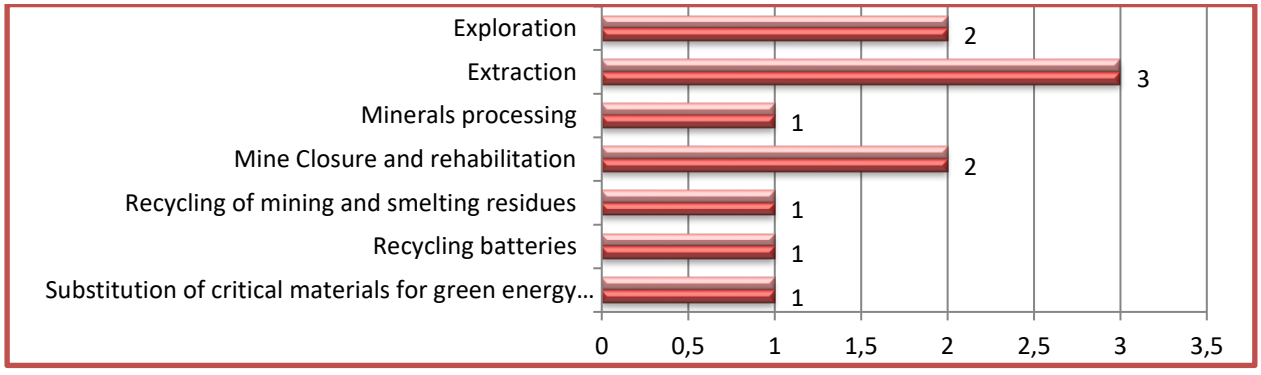


Figure 1 - Distribution of sub-topics addressed in the 6 funded projects.

The type of organisations with the highest participation in the 6 funded projects were public research organisation, representing 31%, and higher education institution with a participation of 30% (*Figure 2*).

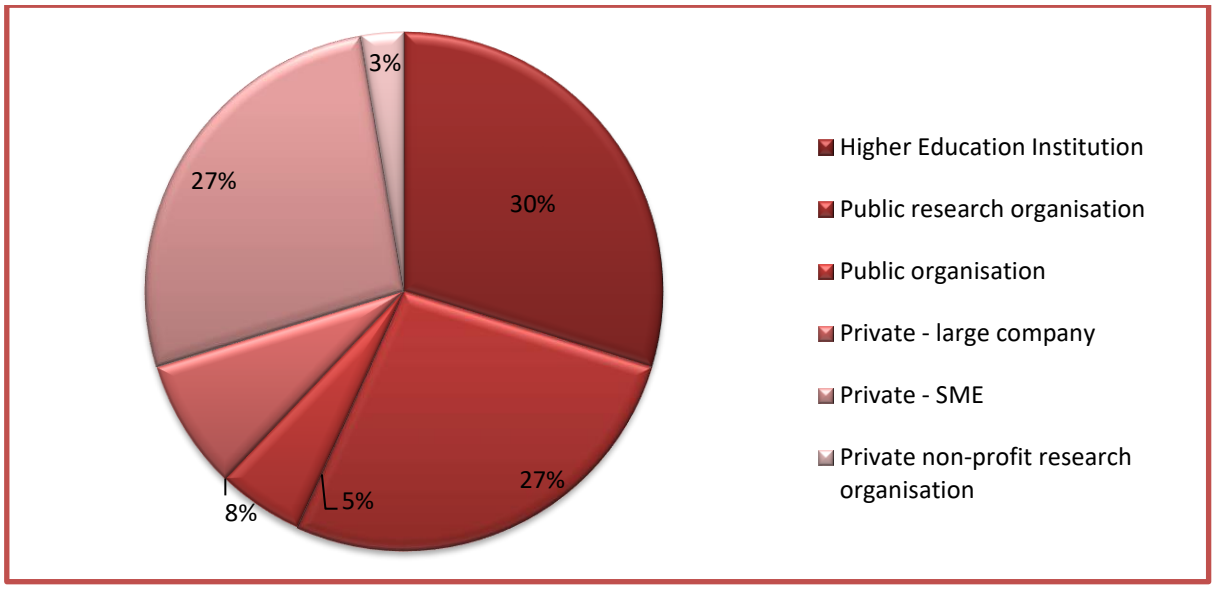


Figure 2 - Distribution of types of organisations in the 6 funded projects.

In terms of country participation, 8 out of 9 countries participating in this Joint Call funded at least two national/regional organisations of the 6 funded projects (*Figure 3*).

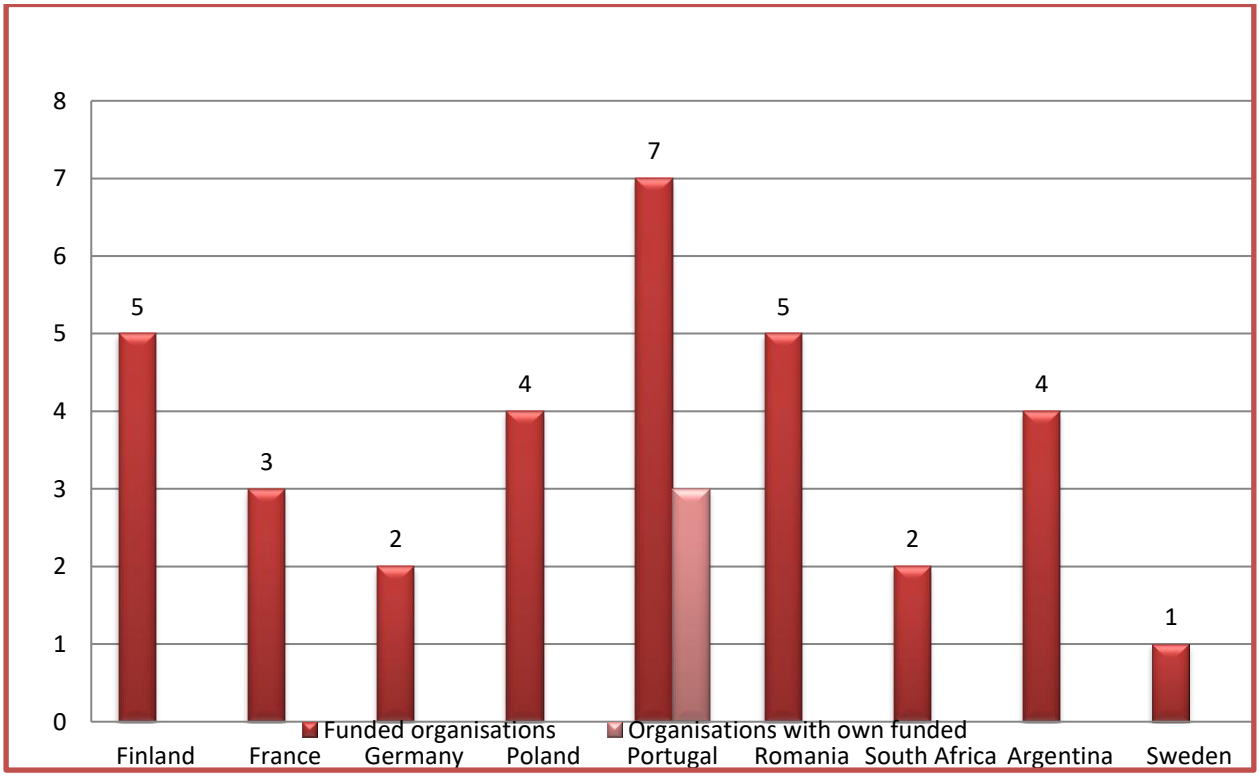


Figure 3 - Geographical participation in the 6 funded projects.

All funded projects involved 40 young researchers which represents the 27% of researchers participating in these projects (*Figure 4*).

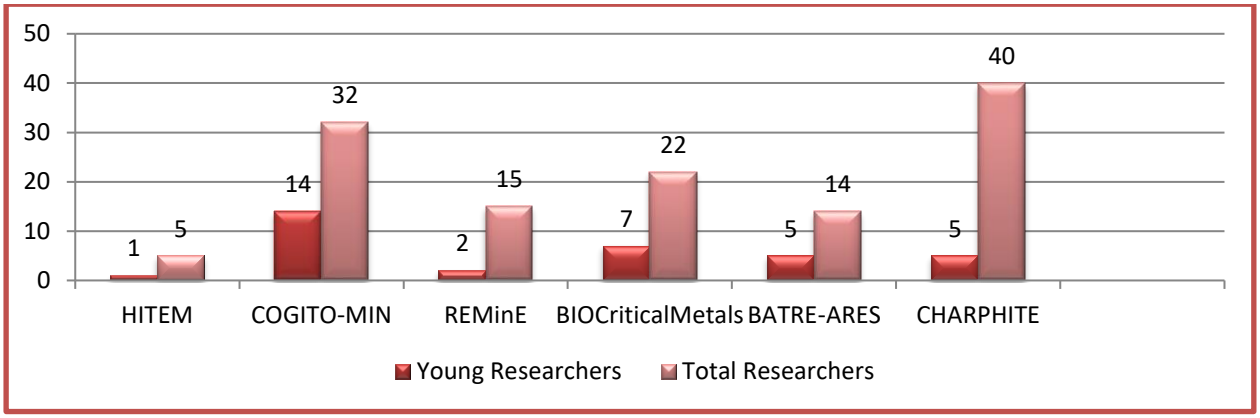


Figure 4 – Young and total researchers participating in the 6 funded projects.

It is highlighted mentioned that 50% of the researchers involved in these funded projects are female which represents a good indicative of gender balance (*Figure 5*).

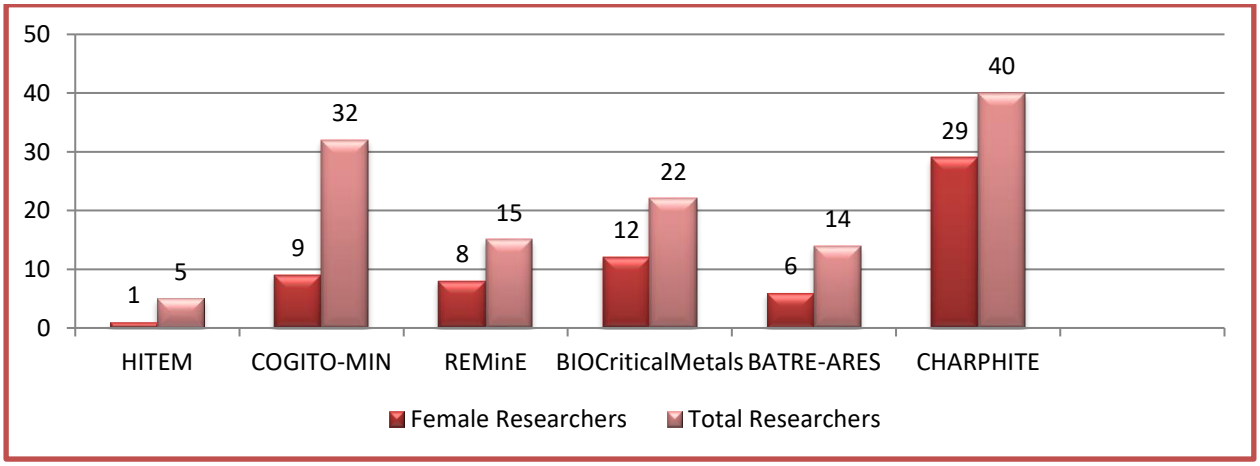


Figure 5 - Female and total researchers participating in the 6 funded projects.

These projects have produced 205 publications (Annex I), 1 patents/licenses & 3 thesis (Annex II) as well as created 1,5 permanent jobs and 40 temporary jobs.

New industrial collaborations have been created through the funded projects and the continuation of these collaborations have been strengthened, being very important the role developed by the industrial sector in the funded projects.

Project BATRE-ARES

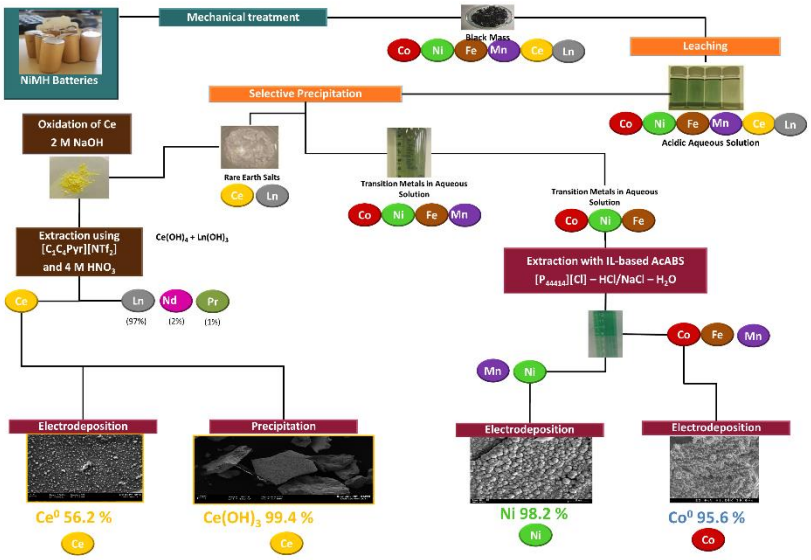
Battery Recycling – Achieving Rare Earth Separation

Sub-topic: 2.F – Metallurgical extraction;
2.G – Closing the loop from an integrated approach.
Project Coordinator: LEPMI (CNRS Délégation Alpes) (France)
Consortium partners:
University of Aveiro (Portugal); G-SCOP (France); Recupyl (France)

Project total funding: € 662.609
Project total costs: € 1.023.991
Duration: 40 months (2016-2019)

SUMMARY and RESULTS:

BatresAres project, supported by ERA-MIN network and co-financed by ADEME and FCT agencies, has proposed an innovative process flowsheet based on the use of ionic liquids for spent NiMH batteries recycling. Spent NiMH batteries contain important quantities of so-called critical raw materials (Co, Ni and REE) and could be thus considered as important source of these elements for EU industry. Two French and one Portuguese laboratories have been working together with one French industrial partner on the project.



Spent batteries have been at first ground and subjected to a first mechanical treatment in order to concentrate the valuable elements in the so-called black mass. This black mass was then leached by diluted sulfuric acid at room temperature and after an additional precipitation step, REE were selectively and quantitatively separated from transition metals (Co, Ni and Mn).

The obtained precipitate was, after an additional oxidation step carried out under alkaline condition, dissolved in nitric acid solution and cerium was selectively separated by extraction from other REE using a specific hydrophobic ionic liquid. A quantitative back-extraction then allowed its selective recovery. Other REE were then recovered in mixture by precipitation.

Very innovative alternative was then thoroughly studied for the transition metals selective recovery. The so-called acid aqueous biphasic systems based on hydrophilic and inorganic acid mixture which splits into two immiscible phases under appropriate concentration of both elements have been described and investigated. Upon splitting an ionic liquid rich phase and an acid rich phase are obtained and the studied metals partition selectively between the two phases. It was proved that Ni can thus be selectively separated from Co. Both elements can then be recovered by electrodeposition.

Finally, an environmental impact assessment of the developed recycling scenario has been carried out using Life Cycle Assessment (LCA) methodology. Using LCA results, it was possible to identify the hotspots activities (most impacting activities) and to quantify the contribution of the recycling process configuration parameters in order to support decision making for the more appropriate recycling strategy. These are namely waste flows treatment, energy consumption and the number of reuse cycles of the used ionic liquids.

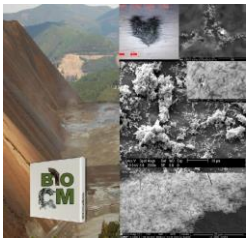
Project BIOCriticalMetals

Recognition of microbial functional communities and assessment of the mineralizing potential (bioleaching) for hightech critical metals

Sub-topic: 1.B - Extraction, 1.E - Mine closure and rehabilitation; 2.A - Recycling of mining and smelting residues (incl. historical dumps and tailings)
Project Coordinator: University of Coimbra (Portugal)
Consortium partners: University of Porto (Portugal), IMNR (Romania), INCDBS (Romania), Universidad Nacional de San Luis (Argentina), EDM (Portugal), Beralt Tin & Wolfram S.A.(Portugal), Geoplano S.A.(Portugal), G.T INGENIERIA S.A. (Argentina), Direction de Mineria de la Provincia de San Luis (Argentina), Comision Nacional de Energia Atomica (Argentina).

Project total funding: € 549.694
Project total costs: € 573.267
Duration: 36 months (2016-2019)
Website:
http://www.uc.pt/en/org/biocriticalmetals

SUMMARY and RESULTS:



The cutting-edge innovative approach of combining microorganisms having the potential to be used in the extraction of metals, with methods (bio & nano) to adsorb these metals was the aim of BIOCriticalMetals. The project, through the contact with stakeholders and industrial partners, made available the methodology developed in the lab to the future exploitation of tailings where potentially critical high-tech metals exist and also to primary sources of these metals, boosting the efficiency of existing mines and expanding the feasibility of the exploitation of small ore deposits.

Definition and characterization of the sample areas (WP1): The objective was to sample and characterize mine waste tailings at the chemical and microbiological level and isolate microorganisms from tungsten and massive sulfide deposits from different climate contexts. The mines selected in Portugal were Panasqueira mine (W and Sn, active, Beraltin&W) and Jales (closed, EDM), in Romania the mines suggested by National Agency for Mineral Resources (ANRM) and General Direction for Mineral Resources and Sustainable Development of Industrial Zones Bălan (county Harghita), Săsar Vechi, Bozânta, Bloaja Vechi, Leorda (county Maramureș), Fagetul Ierii, Baisoara (county Cluj), Fanate (county Bihor), Valea Sesei (county Alba), Valea Mealu (county Hunedoara), Sasca Montana (county Caras Severin) and in Argentina La Carolina mine. The sediments from the target tailings were analysed by ICP and the microbiome of Panasqueira and La Carolina determined by Illumina sequencing. The bacterial isolates were included in UCCCB and NIRDBS culture collections. The deliverables 1.1., 1.2 and 1.3 are included in the publications.

Assessment of the capability of microorganism for bioprocessing critical metals (WP2): The objective was to assess the bioleaching process using microorganisms to mobilize critical metals (tungsten, W; indium, In; gallium, Ga; tellurium, Te; molybdenum, Mo) from mine waste tailings for further processing. Isolates from Panasqueira and La Carolina mines presenting a high tolerance to target metals were selected for bioleaching tests at a small scale. The leaching conditions were optimized by varying the pH, temperature and carbon source. The effect of the presence of a biological consortium on bioleaching ability was also evaluated. The leachates were analyzed by ICP-MS to quantify all the elements released and not only the target metals (by-products). Deliverables 2.1. and 2.2. were fulfilled: identified 1 bacterial able to leach Ga (Rhodanobacter sp. strain B2A1Ga4) 2 strains able to leach Te (Bacillus; Paneabicillus), 1 strain able to leach W (Bacillus 5W24). Siderophores (hydroxamate) were found to be the effector molecules for leaching in that strain (deliverable 2.3). Bioleaching at small scale was demonstrated except for Indium. All results were presented in congresses as oral and poster presentations. The results are also included in publications.

Bioaccumulation strategies with bacteria for leachate treatment (WP3): The objective was to screen metal resistance microorganisms for their ability to accumulate specific metals (W, In, Ga, Te, and Mo) inside the cells and to characterize their accumulative binding capacities. Here was constructed a W hiperaccumulator – EcotupW - using the tup genetic determinants from Sulfitobacter dubius. EcotupW selectively accumulates W in the presence of Mo and Cr. The Bacillus mycoides AlJ98 was showed the accumulate selectively Te in high amounts. Tsukamurella strain B2A2 0.5Te-1 exhibited accumulation of Ga. Mycolicibacterium strain Jales 666 showed high accumulation of In. The genome of the selected organisms was sequenced and is available. Deliverable 3.1 was achieved with the construction of a highly efficient W accumulator (EcotupW); 3.2 (bioaccumulators) were achieved for W, Te, Mo. Deliverable 3.3. was achieved for W and Te genetic determinants. All results were presented at congresses and published in high impact journals.

Development of experimental reactors for selected cases focused on the use of microbial consortiums (WP4): The objective of this WP was to test, at different scales, a selected group of organisms and processes selected considering the results of WP3. The selected strains were used to leach the Panasqueira tailings and the Romania tailings from Bonzanta and Fânate. The upscale of the leaching experiments was performed with fix bead columns. The bioleaching dynamic showed that pore water had 10x more metal concentration than percolating water. The concept for biological extraction of metals from tailings was proposed associating bioleaching and negative pressure extraction of the leachate. The deliverables 4.1. and 4.2 were presented at 2 congresses. The concept for metal removal from sediments include (deliverable 4.3) bioaugmentation with autochthonous microorganisms and negative pressure to obtain pore water.

Assess the wastes produced by bioleaching and mixed (bio-nano) treatment (WP5): The objective was to assess the geochemical composition of the solid wastes obtained from WP2 and the chemical composition of the leaching liquid from the wastes produced after metal recovery in WP3. XRD determined composition of the sediments after bioleaching were obtained from Romanian mine sediments of Fânate. The bioleachate composition of Panasqueira mine tailings using different bacterial strains was determined by IP-MS. The leachates were rich in Cu and Zn and low in W. The characterization of the sediments and solutions after bioleaching (deliverables 5.1 and 5.2) were determined for all the experiments and can be assess in a database. The deliverable 5.3 was not achieved.

Synthesis, communication, coordination (WP6): The objectives were to create the necessary governance structure for an effective implementation and management. All deliverables were achieved and we consider that at least in Portugal the project had high impact in the company Beraltin. All information is available at the Website (https://www.researchgate.net/project/EU-H2020-ERA-MIN-2-BIOCriticalMetals).

Project CHARPHITE

Coal char as a substituting material of natural graphite in green energy technologies

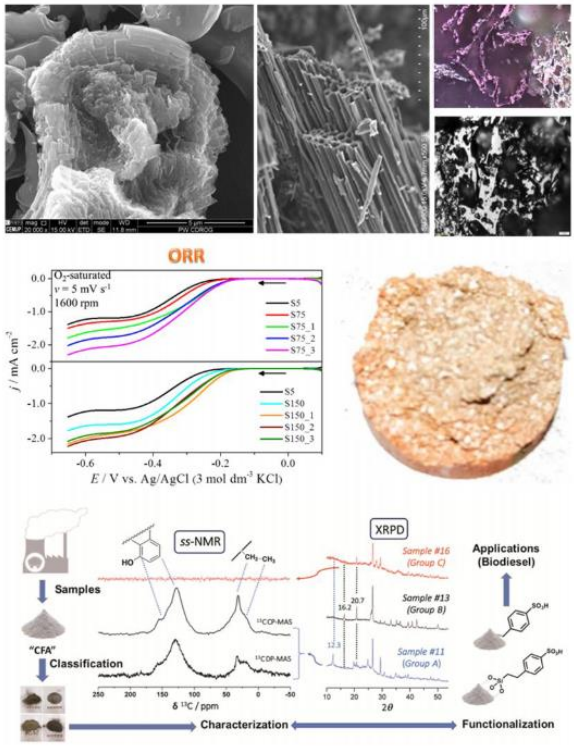
Sub-topic: Extraction, Minerals processing, Mine closure and rehabilitation, Recycling of mining and smelting residues (incl. historical dumps and tailings)

Project Coordinator: University of Porto (Portugal)

Project total funding: € 1.822.371
Project total costs: € 2.481.175
Duration: 45 months (2016-2019)

Consortium partners: University Politehnica Buchares (Romania); REQUIMTE (Portugal); UBA & CONICET (Argentina); University "Constantin Brancusi" of Targu Jiu (Romania); CENTRAL MINING INSTITUTE (Poland); CARBO-GRAF SP. Z O.O. (Poland); University of Johannesburg (South Africa); Pegop–Energia Eléctrica, S.A. (Portugal)

SUMMARY and RESULTS:



The project aimed to demonstrate the technical feasibility to utilize coalCHAR recycled from fly ash andbottom ash as a substitute for graphite-based materials for applications as catalysts in electro-assistedreactions for sustainable energy production: oxygen reduction reaction (ORR) for fuel cell technologyand water splitting.Coal combustion ash samples from Portugal, Poland, Romania and South Africa were selected todetermine a suitable separation procedure. Following ash characterization, the chars were extractedusing several combinations of particle size, elutriation electrostatic, and magnetic separation steps. Thefinal product grade was up to 75 wt. % carbon. The anisotropy percentages of the samples rangedbetween 22 and 49 %; the reference natural graphite sample had anisotropy of 86 %, and Ramanmicrospectroscopyclassified the char concentrates as being "transitional" with the possibility as aprecursor for synthetic graphite.

Fly ash samples from different sources and size fractions were selected to prepare solid acid catalysts tobe used in the transformation ofbiomass derivatives into fuel additives and biofuels production,including esterification of levulinic acid for the preparation of n-butyl levulinate. n-Butyl levulinate wasunique product with conversions up to 100 % after 40 min. reaction. The most promising catalyststudied also exhibited the highest TOFs (447 h-1) and showed to be the most stable and reusable for 5consecutive catalytic cycles. The 13C ss-NMR experiment shows all the expected carbon resonancesignals according to the chemical modification performed. The use of CFA from different sources anddifferent particles sizes endeavor to evaluate the potential effect of: i) different particle sizes; ii) metaloxides composition and carbon content in the final functionalization and catalytic esterification activity. For the electrocatalytic studies, each fly ash was separated by size-25, 45, 75 and 150 um–and testedfor the ORR. All samples showed a dependency between the ORR electrocatalytic activity and theparticles size/composition.For char concentrates, demineralized char concentrates and graphitized char concentrates, in N2-saturated electrolyte, no electrochemical processes are observed for all the samples tested, includinggraphene flakes (GF) whereas, in the presence of O2, all samplesshowed an irreversible reduction peakat 0.63≥Epc≥ 0.75 corresponding to the reduction of oxygen. For the set of concentrated and furthercarbonized samples two samples showed number of electrons transferred per O2 molecules withñ= 2.7and 2.8, suggesting a mix 2-/4-electron pathway.For concentrated and demineralized chars followed by graphitization, the best result was ñ of 3.0 eventhough lowerjLandEonsetvalues were obtained. The electrocatalytic results obtained show that theproject goal touse chars derived from coal fly ash and coal bottom ash as a substitute for graphite-based materials in green energy applications was achieved, and all materials were successfully used inthe electro-assisted energy reaction–oxygen reduction reaction (ORR).Preliminary tests to assess future work were made using laboratory technology of CHAR carbonizationrecovered from the low rank coals and laboratory technology of CHAR pre-graphitization in microwavefield from high rank coals.Tests were made on inorganic residues left for both lightweight construction materials, as well as forhydraulic or ceramic bonding, for different types of by-products and the results were promising, thuscontributing to sustainable waste management and zero waste directives.

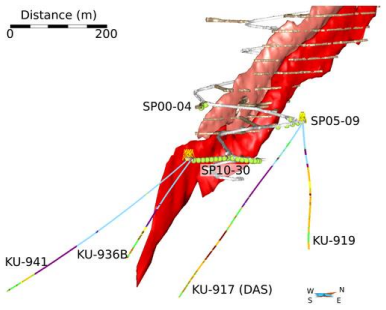
Project COGITO-MIN

COst-effective Geophysical Imaging Techniques for supporting Ongoing MINeral exploration in Europe

Sub-topic: Sustainable Supply of Raw Materials in Europe.
1.A - Exploration, 1.B - Extraction
Project Coordinator: UH (Finland)
Consortium partners: IG PAS (Poland); GTK (Finland); Vibrometric Oy (Finland); Boliden FinnEx Oy (Finland); GP (Poland)

Project total funding: € 1.143.856
Project total costs: € 1.881.110
Duration: 36 months (2016-2018)
Website: https://www.cogito-min.eu

SUMMARY and RESULTS:



The overall aim of COGITO-MIN was to develop cost-effective geophysical mineral exploration techniques, with new advances in particular in data acquisition, processing and interpretation of passive and active-source surface and borehole seismic data (Koivisto et al. 2016, 2018). In 2016, COGITO-MIN acquired an extensive seismic dataset in the Kylylahti sulphide mine and exploration area in Finland. The COGITO-MIN experiments included (i) a 3D passive seismic survey in which ~1000 receivers in a 3.5 x 3 km grid were left to record ambient noise sources for 30 days (Chamarczuk et al. 2018, 2019), (ii) two approximately 6-km long high-resolution seismic reflection 2D profiles (Heinonen et al. 2019), (iii) a sparse active-source 3D seismic reflection survey utilizing the passive seismic grid and a "random" distribution of Vibroseis and explosive sources (Singh et al. 2019), and (iv) a multi-azimuth walk-away three-component Vertical Seismic Profiling (VSP) survey in three boreholes starting from the mine tunnels, with one borehole instrumented also with fibre-optic Distributed Acoustic Sensing (DAS) technology (Riedel et al. 2018) in collaboration with Silixa. The experiments were designed with different stages of the exploration workflow in mind; from mapping of the ore host rocks at larger scale to high-resolution near-mine and in-mine exploration. Seismic surveys were supported by petrophysical measurements (Luhta 2019) that provide constraints for interpretation of the dataset.

High-resolution 2D reflection profiles confirmed the depth-extent of the Outokumpu assemblage rocks that host the mineralizations in the Kylylahti area. These rocks manifest themselves in form of increased piecewise reflectivity, which provides interesting targets for further investigations (Heinonen et al. 2018). A specialized pre-stack depth imaging (Hlousek et al. 2015) was tested in co-operation with TU Bergakademie Freiberg. This so called Fresnel Volume Migration outperformed a more traditional time imaging approach, especially in imaging shallow steeply dipping contacts. Heinonen et al (2019) demonstrated that seismic reflection profiling combined with this type of depth imaging can be a powerful tool even when source access is limited, encouraging more frequent, cost-effective seismic mineral exploration efforts also in greenfield areas. Sparse and irregular active-source 3D survey provided new details about the architecture of the Kylylahti area, in particular about the spatial extent of the Outokumpu assemblage rocks. Similar to 2D imaging, a significant uplift in imaging was brought by the pre-stack depth imaging (Singh et al. 2019). The results show that a sparse 3D active-source survey is a viable, cost-effective option when a full active-source 3D survey is not possible. VSP results, involving development of a VSP imaging scheme corroborated by detailed forward modelling and interpretation workflow, led to successful interpretation of key geological contacts including the target sulphide mineralization (Riedel et al. 2018). The results demonstrate the value of tailored in-mine VSP measurements for in-mine exploration and resource delineation in a complex geological setting, especially when coupled with the fiber-optic DAS technology which provides reflection data of sufficient quality with less logistical efforts. To our knowledge this was the first time that DAS technology was tested in a crystalline rock mining environment. The VSP data acquisition and processing workflows can be readily applied to new sites and are offered as a commercial service by Vibrometric.
Within COGITO-MIN project, also a new software was tested by Geopartner for joint inversion of 2D gravity and audio-magnetotelluric (AMT) data. The tests provided new information for developing the software. However, in the Kylylahti-type geological environment a 3D magnetotelluric survey would be more applicable. The COGITO-MIN seismic data successfully delineate the main geological contacts in the Kylylahti area. The COGITO-MIN dataset is jointly interpreted with other geological and geophysical data, e.g. AMT data and earlier 2D reflection seismic profiles from the area, to construct a 3D model of the main geological contacts. Tests are being run to parameterize and integrate seismic data into an exploration workflow.

Project HITEM

Highly sensitive receiver for measuring transient electromagnetic responses in Exploration for deep buried mineral occurrences

Sub-topic: Primary resources: exploration, extraction, minerals processing, metallurgy, mine closure and rehabilitation. 1.A –Exploration.

Project Coordinator: SUP (Germany)

Consortium partners:
BBG (South Africa); Leibniz IPHT (Germany); GRM - SMOY (Finland)

Project total funding: € 969.611
Project total costs: € 1.152.069
Duration: 41 months (2016-2019)

SUMMARY and RESULTS:

The potential for exploring resource deposits deeper than 500m from the surface is limited by geophysical techniques. One method successfully applied to date is so-called transient, time domain or pulse electro-magnetics (TEM). For volcanogenic massive sulphide deposits (VMS as a subspecies of volcanic exhalative deposits), conventional measurement techniques have already been able to achieve exploration depths of up to a few hundred metres. In addition to non-ferrous metals, these VMS deposits usually also contain significant amounts of platinum and platinum group elements, including platinum, palladium, ruthenium, iridium, rhodium and osmium. All of them contain valuable high-tech metals, which are necessary for future technologies.

Electromagnetic exploration methods, such as TEM, are excellently suited for this type of deposit, as the metals have an increased electrical conductivity. Due to the previous limitation of the exploration depth, however, very little is known about the depth extension of the deposits. This applies in particular to Germany, where after centuries of intensive mining, superficial resources are considered to be exhausted as far as possible.In thisproject, the researchers have advanced this technology in order to enable extended penetration depths and to explore VMS deposits for the acquisition of high-tech metals. In the "HiTEM" project, a higher penetration depth of the method was not achieved byincreasing the transmitter pulse moment, but by increasing the sensitivity of the sensors and the entire TEM receiver, particularly in the low-frequency range. This enabled to make use of later times in the TEM signal decay after the transmitter pulse hasbeen switched off. This task was solved by means of new Superconducting Quantum Interference Detectors (SQUID) based on high-temperature superconducting (HTS) materials. The development of robust, low-noise HTS-SQUID sensors was part of the work of Leibniz IPHT and was successfully realised. The new sensors are faster to be fabricated, can be assembled and encapsulated in fewer processing steps as well as they are more robust in operation which makes them more cost-effective. For this purpose, new fabrication tools and technologies were implemented in the fabrication line. The performance of the sensors wascharacterized by the advanced and adapted receiver electronics. For the first time, control electronics based onhigh-frequency AC Bias were developed and implemented for all three sensors. In the interaction of sensors and electronics, the system noise could be reduced, especially in the low-frequency frequency range, thus achieving a high signal quality and a greater depth of investigation. The control electronicsand all indicators arenow fully digitaland transferred to a browser-based solution, so that now no complex installation of additional software for setting the systems and system parameters is necessary. The field tests in Finland and possibly other countries on representative targets of this deposit type are to be completed in this year. Initial results on the improved system parameters have already been determined and validated. Within the scope of further field measurements, these results will be verified in the field (Finland) and the developed innovativemethods for the reduction of electromagnetic noise in the corresponding frequency range for TEM will be analysed, validated and optimized. In addition, new inversion and interpretation methods could be further developed and implemented. Due to different aspects the project had been prolonged by 6 monthsand ended in October 2019.The project results prove that the expectations of the partners involved were fulfilled. Against this background, SUPRACONbelieves that a new, robust technology has been developed that will enable exploration service providers and mining companies to make more accurate statements about potential deposits. This might be accompanied by a potential reduction in the number of drill holes required, as the expected deposits can be determined more accurately.

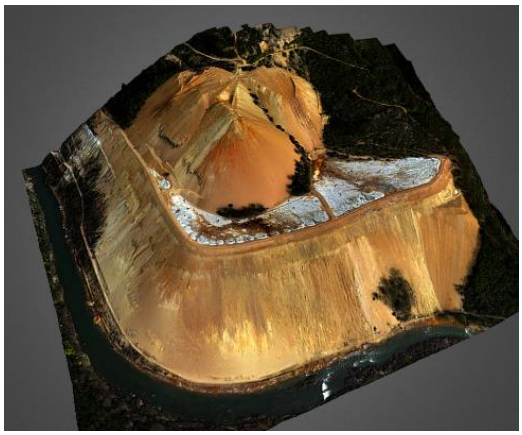
Project REMinE

Improve Resource Efficiency and Minimize Environmental Footprint

Sub-topic: Extraction, Mine closure and rehabilitation, Minerals processing
Project Coordinator: LTU (Sweden)
Consortium partners:
INCDMRR (Romania); FEUP (Portugal)

Project total funding: € 871.056
Project total costs: € 1.021.207
Duration: 36 months (2016-2019)

SUMMARY and RESULTS:



The REMinE project is organized in five work packages (see section 2) that comprise: project management (WP1), detailed characterization of the mining wastes selected (WP2), identification of new processing methods for treating ancient tailings (WP3), characterization and risk assessment of the tailings and neo-tailings (WP4), outlining business opportunities and environmental impact in a conceptual model for sustainable mining (WP5).
The project comprises case studies of historical mine wastes from three different European countries, namely Portugal, Romania and Sweden.
The interdisciplinary research collaboration in this project is innovative in the sense that separation of minerals and extraction of metals are based not only on technical and economic profit but also consider the environmental perspective. This might lead to an understanding that environmental benefits and social responsibility should be of equal importance in comparison with economic feasibility. The project includes detailed characterization and risk assessment of the wastes, identification of new processing methods and process design, outlining of business possibilities, and a risk assessment for the remaining residuals. The main results will lead to a conceptual model as guidance for the further sustainable development of mining. Main achievements FEUP: Extensive sampling of the tailings disposal allowing its mineralogical, physical, chemical, and environmental characterization; construction of 3-D geo-referenced model of the tailings embankment; flowsheet for an integrated processing of the tailings that includes removal of arsenic by flotation and recovery of tungsten and zinc by hydrometallurgical methods; quantitative environmental and toxicological risk assessment; proposal of a methodology for optimizing a multi-criteria solution. Main achievements LTU: High content of Be, Bi, Cu, Sn, W, Zn, F and S in the were found in the Yxsjöberg tailings, Sweden. Long-term storage in ambient conditions has generated a oxidized environment which is characterized by complete oxidation of pyrrhotite, depletion of calcite, decreased pH from >8 to <4,weathering of fluorite and small parts of silicates, and formations of secondary gypsum and amorphous hydrous ferric oxides. The release of elements from the tailings have decreased the quality of surface water downstream the tailings. The most critical major element was F, which was found in concentrations (2.6 mg/L) that can have moderate to severe effects on humans. Trace elements of high potential concern to leach out with the mine drainage is Be and Zn. Tungsten was released to the groundwater of the tailings and into surface water downstream the tailings. However ,the concentrations were not large enough to be classified as a contaminant according to today's water regulations. Drill cores taken from the tailings deposit were classified according to their mineralogical and processing properties. Based on metallurgical test work a flowsheet has been developed that involves enhanced physical separation and flotation. Product streams were analysed with respect to multiple objectives as recovery of valuable minerals and environmental risk from new tailings. Main achievements INCDMRR: The tailings showed high potential of acid releases. The processing of the tailings by flotations allows to concentrate more than 70% of the arsenic. Besides that, the depressed material is enriched in tungsten with lower arsenic content allowing for its recovery. The technical aspect of tailings reprocessing was done by multi-objective parametric optimization (W and Zn grades and recoveries) based on mathematical models and processing laboratory results for flotation and leaching.

ANNEX I:

❖ Project BATRE-ARES:

Title	Link (doi or similar)
Article 1: Nicolas Schaeffer, Matthieu Gras, Helena Passos, Vijetha Mogilireddy, Carlos M. N Mendonça Eduarda Pereira, Eric Chainet, Isabelle Billard, João A. P. Coutinho, and Nicolas Papaiconomou; "Synergistic aqueous biphasic systems: a new paradigm for the 'onepot' extraction of critical metals", ACS Sustainable Chemistry and Engineering, 2019, 7, 1769-1777	https://doi.org/10.1021/acssuschemeng.8b05754
Article 2: Nicolas Schaeffer, German Pérez-Sánchez, Helena Passos, José R.B. Gomes, Nicolas Papaiconomou, João A. P. Coutinho; "Mechanisms of Phase Separation in Temperature–Responsive Acidic Aqueous Biphasic Systems", Physical Chemistry Chemical Physics, 2019,21, 7462-7473	https://doi.org/10.1039/C8CP07750A
Article 3: Matthieu Gras, Nicolas Papaiconomou, Nicolas Schaeffer, Eric Chainet, Farouk Tedjar, João A. P. Coutinho, Isabelle Billard; "Ionic-Liquid-Based Acidic Aqueous Biphasic Systems for Simultaneous Leaching and Extraction of Metallic Ions", Angewandte Chemie, 2018, 57, 1563-1566.	https://doi.org/10.1002/anie.201711068
Article 4: Nicolas Schaeffer, Helena Passos, Matthieu Gras, Vijetha Mogilireddy, João P Leal, German Perez-Sanchez, José R. B. Gomes, Isabelle Billard, Nicolas Papaiconomou, and João A. P. Coutinho; "Mechanism of ionic liquid-based acidic aqueous biphasic systems formation", Physical Chemistry Chemical Physics, 2018, 20, 9838-9846.	https://doi.org/10.1039/C8CP00937F
Article 5: Vijetha Mogilireddy, Matthieu Gras, Nicolas Schaeffer, Helena Passos, Lenka Svecova, Nicolas Papaiconomou, João A. P. Coutinho, and Isabelle Billard; "Understanding the fundamentals of acid-induced ionic liquid-based aqueous biphasic system", Physical Chemistry Chemical Physics, 2018, 20, 16477-16484.	https://doi.org/10.1039/C8CP02862A
Article 6: Nicolas Schaeffer, Helena Passos, Isabelle Billard, Nicolas Papaiconomou, and João A. P. Coutinho; "Recovery of metals from waste electrical and electronic equipment (WEEE) using unconventional solvents based on ionic liquids", Critical Review in Environmental Science and Technology, 2018.	https://doi.org/10.1080/10643389.2018.1477417
Article 7: Matthieu Gras, Nicolas Papaiconomou, Eric Chaînet, Farouk Tedjar, Isabelle Billard, Separation of cerium (III) from lanthanum (III), neodymium (III) and praseodymium (III) by oxidation and liquid-liquid extraction using ionic liquids Separation and Purification Technology, 178 (2017) 169-177.	https://doi.org/10.1016/j.seppur.2017.01.035

❖ Project BIOCriticalMetals:

Title	Link (doi or similar)
Master thesis of Francisco Vieira in Master in Geology of from Department of Earth Science, Faculty of Sciences and Technology, University of Coimbra in 2017.	https://eg.uc.pt/handle/10316/15518
Master thesis of Márcia Ansiães in Master of Applied Ecology from Department of Life Sciences, Faculty of Sciences and Technology, University of Coimbra entitled "Tungsten bioaccumulation trough bacterial utilization: development and optimization of tungsten absorbent and/or tungsten chelating bacteria", in 2018.	https://eg.uc.pt/handle/10316/15518
Master thesis of Joana Caldeira in Biochemistry Master from Department of Life Sciences, Faculty of Sciences and Technology, University of Coimbra entitled "Biological Mechanisms for the Control of Oxidative Stress Induced by Critical Metals in Bacteria", in 2018.	https://eg.uc.pt/handle/10316/15518
Master thesis of Merijn Moens in International Master of Applied Ecology (IMAE) from Department of Life Sciences, Faculty of Sciences and Technology, University of Coimbra entitled "Ochrobactrum tritici immobilized in Oryza sativa, sodium polyacrylate and alginate as a novel bioremediation tool", in 2017.	https://eg.uc.pt/handle/10316/15518
Fonseca, F.R.M.2017. Master thesis in Biomedical Engineering, Specialty Biomaterials and Medical Instrumentation: "3D Printing of nanocomposites: bacteria as raw material providers"	https://eg.uc.pt/handle/10316/15518
Francisca Barbosa Brás (2017). "Estudo da aptidão de microrganismos autóctones de ambientes mineiros na recuperação de metais críticos", Master Dissertation in Mining and Geo-environment Engineering, Faculdade de Engenharia da Universidade do Porto.	http://hdl.handle.net/10216/108303
Giuditta Romio, Flask and Column Bioleaching Tests by Autochthonous Microbial Community for the Recovery of Heavy Metals from Mining Waste, Dissertation submitted for the degree of MASTER IN ENVIRONMENTAL ENGINEERING.	https://drive.google.com/open?id=1f8q6SS1YcBlPAbfDBOlimDwSuH3X2h-o
Ph.D. thesis of Pedro Farias in Biosciences from Department of Life Sciences, Faculty of Sciences and Technology, University of Coimbra entitled "New bacterial strategies for Tellurium bioleaching and high value nanoparticle production", in 2016. (ongoing).	*(ongoing)*
Chung, A.P., Coimbra, C., Farias, P. et al. Tailings microbial community profile and prediction of its functionality in basins of tungsten mine. Sci Rep 9, 19596 (2019).	https://doi.org/10.1038/s41598-019-55706-6
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Piedade, A., Francisco, R., Branco, R., and P.V. Morais. 2018. Thin films for medical and environmental applications (Chapter), pp 1-13. In: Thin Film Synthesis and Application for Medical and Biological Use.	*IntechOpen. ISBN 978-953-51-6670-2*
Coimbra C., Branco R., Morais P.V. Efficient bioaccumulation of tungsten by Escherichia coli cells expressing the Sulfitobacter dubius TupBCA system. Systematic and Applied Microbiology 42 (2019) 126001.	https://doi.org/10.1016/j.syapm.2019.126001
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Francisco, R., Branco, R., Schwab, S., Baldani, I., and Morais, P.V. Impact of plant-associated bacteria biosensors on plant growth in the presence of hexavalent chromium. World J Microbiol Biotechnol 34, 12 (2018).	https://doi.org/10.1007/s11274-017-2389-0

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Proença DN, Heine T, Morais P.V., Tischler D. 2018. Link between genomic identification and biochemical characterization of novel siderophores produced by endophytic bacteria. In Grenni P., Fernández-López M., Mercado-Blanco J. (Eds). Soil biodiversity and European woody agroecosystem.	*COST Action FP1305 BioLink Linking belowground biodiversity and ecosystem function in European forests, Proceedings of the 2018 Annual Meeting. Granada.*
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Poster: The seismic signature of the Kylylahti deposit: Initial results from new petrophysical measurements. T. Luhta, S. Mertanen, E. Koivisto, S. Heinonen, T. Törmälehto and I. Kukkonen. Lithosphere 2016 Symposium. 9-11.11.2016, Espoo, Finland.	Link to abstract volume: open access (extended abstract): *http://www.seismo.helsinki.fi/pdf/Lito2016.pdf*
Poster: Passive seismic interferometry applied to hardrock exploration: a case study from Kylylahti mine (Finland). Chamarczuk, M., Malinowski, M. and the COGITO-MIN Working Group. 5-9.06.2017, Cargese, Korsyka.	
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Talk: Passive seismic interferometry for subsurface imaging in an active mine environment: case study from the Kylylahti Cu-Au-Zn mine, Finland. Chamarczuk, M., Malinowski, M., Koivisto, E., Heinonen, S., Juurela, S. and the COGITO-MIN Working Group. Exploration`17 Seismic Methods & Exploration Workshop. 26.10.2017, Toronto, Canada.	Link to abstract volume: open access (extended abstract): *http://www.dmec.ca/DMEC/media/Workshops/Seismic%20Methods%20and%20Exploration/Seismic-Methods-Exploration-Workshop-Papers.pdf*
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Talk: Active source seismic imaging in the Kylylahti Cu-Au-Zn mine area, Finland. Heinonen, S., Malinowski, M., Gislason, G., Danaei, S., Koivisto, E., Juurela, S. and the COGITO-MIN Working Group Exploration`17 Seismic Methods & Exploration Workshop. 26.10.2017, Toronto, Canada.	Link to abstract volume: open access (extended abstract): *http://www.dmec.ca/DMEC/media/Workshops/Seismic%20Methods%20and%20Exploration/Seismic-Methods-Exploration-Workshop-Papers.pdf*
Talk: Seismic imaging of the Kylylahti Cu-Au-Zn ore deposit using conventional and DAS VSP measurements supported by 3D full-waveform seismic modelling. Riedel, M., Cosma, C., Komminaho, K., Enescu, N., Koivisto, E., Malinowski, M., Luhta, T., Juurela, S. and the COGITO-MIN Working Group. Exploration`17 Seismic Methods & Exploration Workshop. 26.10.2017, Toronto, Canada.	Link to abstract volume: open access (extended abstract) : *http://www.dmec.ca/DMEC/media/Workshops/Seismic%20Methods%20and%20Exploration/Seismic-Methods-Exploration-Workshop-Papers.pdf*
Talk: Towards adapting seismic interferometry to retrieve body-wave reflections for mineral exploration: the passive seismic experiment in the KylylahtiCu-Au-Zn mine area, Finland.	

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Talk: Testing of New, Low-cost Seismic Exploration Approaches at Kylylahti Polymetallic Mine Site, Eastern Finland. Koivisto, E., Malinowski, M., Heinonen, S., Cosma, C., Enescu, N., Juurela, S., Wojdyla, M., Chamarczuk, M., Riedel, M. and the COGITO-MIN Working Group. EAGE NSG 2018 Workshop: Worldwide Mineral Exploration Challenges and Cost-Effective Geophysical Methods. 9.9.2018, Porto, Portugal.	Link to the event: *https://events.eage.org/en/2018/2nd-conference-on-geophysics-for-mineral-exploration-and-mining/technical-programme/workshop/workshop-1*
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Poster: Passive Seismic Three-Component Interferometry Experiment at the Kylylahti Mine Site, Eastern Finland Väkevä, S., E. Koivisto, M. Chamarczuk, M. Malinowski and the COGITO-MIN Working Group EAGE NSG 2018. 9.-13.9.2018, Porto, Portugal.	Link to extended abstract: *http://earthdoc.eage.org/publication/publicationdetails/?publication=94516* DOI: 10.3997/2214-4609.201802715
Poster: From regional seismics to high-resolution resource delineation: Example from the Outokumpu ore district, Eastern Finland Koivisto, E., Malinowski, M., Heinonen, S., Cosma, C., Vaittinen, K, Wojdyla, M., Chamarczuk, M., Riedel, M., Kukkonen, I. and the COGITO-MIN Working Group EAGE NSG 2018. 9.-13.9.2018, Porto, Portugal	Link to extended abstract: *http://www.earthdoc.org/publication/publicationdetails/?publication=94517* DOI: 10.3997/2214-4609.201802716
Poster: Distributed Acoustic Sensing versus conventional VSP imaging of the Kylylahti polymetallic deposit Riedel, M., Cosma, C., Enescu, N., Koivisto, E., Komminaho, K., Vaittinen, K., Malinowski, M. EAGE NSG 2018. 9.-13.9.2018, Porto, Portugal.	Link to extended abstract: *http://www.earthdoc.org/publication/publicationdetails/?publication=94545* DOI: 10.3997/2214-4609.201802744
Talk: Seismic interferometry for mineral exploration: passive seismic experiment over Kylylahti mine area, Finland	Link to extended abstract: *http://earthdoc.eage.org/publication/publicationdetails/?publication=94504*

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Poster: Seismic exploration in the Kylylahti Cu-Au-Zn mining area: comparison of time and depth imaging approaches Heinonen S, Malinowski M, Hlousek F, Gislason G, Koivisto E, Buske S, The COGITO-MIN Working Group EAGE NSG 2018. 9.-13.9.2018, Porto, Portugal.	Link to extended abstract: *http://earthdoc.eage.org/publication/publicationdetails/?publication=94514* DOI: 10.3997/2214-4609.201802713
Talk: 3C Seismic Interferometry at the Polymetallic Kylylahti Deposit, Outokumpu District, Finland S. Väkevä, E. Koivisto, G. Hillers, M. Chamarczuk and M. Malinowski Lithosphere 2018 Symposium. 14.-15.11.2018, Oulu, Finland.	Link to abstract volume: open access (extended abstract): *http://www.seismo.helsinki.fi/ilp/lito2018/Lito2018_Abstract_Volume_color.pdf*
Talk: COGITO-MIN seismic reflection profiling for mineral exploration in Polvijärvi, Finland S.Heinonen, M. Malinowski, G. Gislason, F. Hlousek, S. Buske and E. Koivisto Lithosphere 2018 Symposium. 14.-15.11.2018, Oulu, Finland.	Link to abstract volume: open access (extended abstract): *http://www.seismo.helsinki.fi/ilp/lito2018/Lito2018_Abstract_Volume_color.pdf*
Talk: Testing of seismic mineral exploration methods at different scales at the Kylylahti polymetallic mine site, Eastern Finland. E. Koivisto, M. Malinowski, S. Heinonen, M. Riedel, M. Chamarczuk, C. Cosma, K. Vaittinen, M. Wojdyła and the COGITO-MIN Working Group. Lithosphere 2018 Symposium. 14.-15.11.2018, Oulu, Finland.	Link to abstract volume: open access (extended abstract): *http://www.seismo.helsinki.fi/ilp/lito2018/Lito2018_Abstract_Volume_color.pdf*

❖ Project HITEM:

Title	Link (doi or similar)
Advanced HTS DC SQUIDs with Step-Edge Josephson Junctions for Geophysical Applications.	*10.1109/TASC.2018.2820056*

❖ Project REMinE:

Title	Link (doi or similar)
Bi-level depth assessment of an abandoned tailings dam aiming its reprocessing for recovery of valuable metals.	*https://doi.org/10.1016/j.mineng.2018.12.016*
Tailings reprocessing from Cabeço do Pião dam in Central Portugal: A kinetic approach of experimental da	*https://doi.org/10.1016/j.jsm.2018.07.001*
Design optimization of a tailings reprocessing: Tungsten and zinc.	*https://doi.org/10.5593/sgem2018/2.1/S07.03*
Improving Resource Efficiency and Minimize Environmental Footprint – a case study preliminary results.	*http://www.imwa.info/docs/imwa_2017/IMWA2017_Albuquerque_1240.pdf*
Tailings: re-processing or safe storage? A proposal of optimization by multi-objective criteria.	*https://cest.gnest.org/sites/default/files/presentation_file_list/cest2017_01235_poster_paper.pdf*
Physical chemical characterization of historical mining waste.	*https://doi.org/10.1051/e3sconf/201712301031*

Design optimization of a tailings reprocessing: tungsten and zinc recovery.	https://doi.org./10.55932/sgem2018/2.1
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Bi-level depth assessment of an abandoned tailings dam aiming its reprocessing for recovery of valuable metals.	http://www.min-eng.com/sustainableminerals18/paps.html
Recovery of Arsenic by flotation – A case study on the tailings of Cabeço Do Pião.	https://sigarra.up.pt/feup/pt/pub_geral.pub_view?pi_pub_base_id=2538
Are tailings sources ofsecondary raw materials?	https://drive.google.com/open?id=16qDEzOFQ8eadQnIoYrmDj0stJULh1VlE
Mining wastes in a circular Economy.	https://drive.google.com/open?id=14BmV38WHX5OzGIfvEWqsNLe3wxhieRnh
Historical mine waste characterization: an approach for environmental wastes management and metals recovery.	https://drive.google.com/file/d/1CCOuExjAiiFDQ0C9Z-6eq75TLzKi71zT/view?usp=sharing
Circular statistical models in the studies of the atmospheric dispersion of particles from mining tailings dams.	https://drive.google.com/file/d/1Y2D2b_-4BlUmDeNXemCyNYcXCGubqc4O/view?usp=sharing
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Remining and Restructure of a Tailing Deposit - Technical Feasibility.	http://hdl.handle.net/10216/105289
Geochemical Characterization of Historical W, Cu and F Skarn Tailings at Yxsjöberg, Sweden (2018). With focus on scheelite weathering and tungsten (W) mobility.	http://ltu.diva-portal.org/smash/get/diva2:1249767/FULLTEXT01.pd
Geochemical Characterization of W, Cu and F Skarn Tailings at Yxsjöberg, Sweden. J. Geochem Explor. 194:266-279.	*DOI: 10.1016/j.gexplo.2018.09.001*
Metal Release from Acidic and Near-Neutral pH-Conditions in Historical W, Cu and F Skarn Tailings at Yxsjöberg, Sweden.	https://www.imwa.info/docs/imwa_2018/IMWA2018_Hallstrom_351.pdf
Strontium (87Sr/86Sr) isotopes: A tracer for geochemical processes in mineralogically-complex mine wastes.	https://www.sciencedirect.com/science/article/pii/S0883292718303081?via%3Dihub
Physical chemical characterization of historical mining waste and ARD prediction tests.	*E3S Web of Conferences, 2017BDI10.1051/e3sconf/20171801031*
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THE OXIDATIVE PROCESSES AND MIGRATION OF ELEMENTS IN HISTORICAL TAILINGS.	*Proceedings- XIII International Mineral Processing and Recycling Conference ISBN 978-86-6305-091-4*
Characterization and Feasible Physical Separation Methods for Yxsjöberg Historical Tungsten Ore Tailings. Luleå Conference in Minerals Engineering 2019.	https://www.ltu.se/cms_fs/1.79916!/file/Preliminary%20list%20of%20papers%202019.pdf
Feasibility of gravity and magnetic separation for Yxsjöberg historical tungsten ore tailings. Physical separation ’19.	http://www.min-eng.com/physicalseparation19/paps.html

ANNEX II:

Funded project	Title	Reference
Project BATRE-ARES: **Patent**	Ionic liquid-acid aqueous systems. Papaiconomou N., Coutinho J., Gras M., Billard I.,	WO 2018/087364 Al. Published 17/05/2018 *https://patents.google.com/patent/WO2018087364A1/fr?q=syst%C3%A8me&q=biphasique&q=aqueux&oq=syst%C3%A8me+biphasique+aqueux*
Project COGITO-MIN: **Theses**	Petrophysical properties of the Kylylahti Cu-Au-Zn sulphide mineralization and its host rocks. Luhta, T.; University of Helsinki; MSc; Publication: 2019.	*https://helda.helsinki.fi/handle/10138/302130*
Project COGITO-MIN: **Theses**	Using Three-Component Data for Seismic Interferometry Studies at the Kylylahti Mine, Eastern Finland. Väkevä, S.; University of Helsinki; MSc; Publication: 2019.	*https://helda.helsinki.fi/handle/10138/302127*
Project COGITO-MIN: **Theses**	2 PhD theses underway at IG PAS. Chamarczuk, M. and Singh, B.; IG PAS; PhD. Publication 2020-2022.	