UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Campus de Manresa

Doctorat en Recursos Naturals i Medi Ambient de la UPC Manresa

Llibre resum de tesis doctorals en curs.

Juliol 2024.

Doctorat en Recursos Naturals i Medi Ambient de la UPC Manresa

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CONTINGUTS

PREÀMBUL

Aquest llibre digital que tens a la vista conté un retrat actual de la recerca reglada en forma de programa de Doctorat en Recursos Naturals i Medi Ambient de la UPC Manresa. Respon a l'impuls que des de l'Escola de Doctorat de la Universitat Politècnica de Catalunya es vol donar a tots els seus centres i campus. Iniciat l'any 1992 el programa té la missió de nuclear la recerca interdisciplinària que es fa al si del campus de Manresa de la UPC al cor de la Catalunya Central, i així contribuir significativament a la retenció de talent en aquest territori.

En *primer lloc* destacar la fortalesa del **caràcter interdisciplinari de la recerca del programa.** L'àmbit va néixer a la intersecció entre la geologia, la química i l'enginyeria allunyant-se de la hiperespecialització temàtica regnant fa més de trenta anys. Aquesta mirada àmplia li ha permès ser pionera en els temps actuals on es multipliquen les visions més obertes i holístiques fonamentades en la base d'excel·lir. Per això el programa es focalitza en la cruïlla dels recursos naturals.

A més els directors de tesis han estat distingits amb reconeixement docent com premis extraordinaris o les màximes distincions internes i externes a la pròpia universitat en recerca i transferència. A més d'haver estat reconeguda la seva excel·lència pels governs de Catalunya i de l'estat. Des de la recerca bàsica a l'aplicada fins a la innovació.

En *segon lloc* contribuir significativament a la **retenció de talent al territori**. En els primers anys aconseguí formar doctors que han format part de la pròpia Escola, afavorint el creixement del percentatge de doctors a l'EPSEM; però també del centre tecnològic Eurecat a Manresa i dels centres tecnològics i departaments d'innovació de les principals empreses en ciutats referents de la perifèria de Barcelona i així ha contribuït significativament a la retenció de talent al territori de les comarques de la Catalunya Central.

Els àmbits d'expertesa s'han expandit des de la biomecànica fins a la sostenibilitat passant per la microbiologia. Ben aviat, cap a l'any 2000 amb un curs amb estudiants de 3 continents ja es va assolir una dimensió internacional notòria, com a la resta de programes de doctorat vigents del sistema universitari català. Aquesta dada juntament amb una igualtat de gènere entre les direccions de tesi propera al 40% han mantingut una singularitat a l'alça en un ambient politècnic més desigual incorporant al seu panell d'egressats els primers doctors industrials que han contribuït a una millora del coneixement sobre l'aprofitament dels recursos naturals de manera respectuosa amb el medi ambient.

Francesc Xavier de las Heras i Cisa

Professor emèrit
Catedràtic Universitat Politècnica de Catalunya
Departament d'Enginyeria Minera, Industrial i TIC

INTRODUCCIÓ

L'Escola de Doctorat de la Universitat Politècnica de Catalunya presenta la segona edició del llibre recull de tesis del Programa de Doctorat de Recursos Naturals i Medi Ambient que s'imparteix a l'Escola Politècnica Superior d'Enginyeria de Manresa (EPSEM), el campus de la UPC a la capital del Bages.

L'any 1992 a iniciativa del Departament d'Enginyeria Minera i Recursos Naturals, la UPC va començar a impartir a l'Escola Politècnica Superior d'Enginyeria de Manresa, aquest nou programa de doctorat. Just aquell any, se celebraven 20 anys de la incorporació de l'EPSEM a la UPC.

D'aquesta manera, es feia una important ampliació de l'oferta de l'Escola que ha permès consolidar formació de professionals de primer nivell amb capacitat de donar resposta als problemes i reptes mediambientals, climàtics i d'aprofitament sostenible dels recursos naturals. Avui, el repte més important a nivell mundial és l'emergència climàtica i les seves conseqüències sobre els ecosistemes i els models de vida. Des de l'EPSEM, amb el programa de doctorat es garanteix la formació de doctors i doctores amb la preparació i formació per poder-hi fer front.

És important destacar que des de la seva obertura, a través del programa s'ha garantit que l'EPSEM i el conjunt del territori disposi de formació universitària en tots els seus nivells, des de grau universitari fins a doctorat. I que a més, el programa de Recursos Naturals i Medi Ambient és actualment i des de 1992 l'únic doctorat que s'imparteix a la comarca del Bages. És a dir, l'únic instrument de formació de noves doctores i doctors del territori amb tot el que això comporta. El programa és avui al Bages un element tractor, amb rodatge i de solvència contrastada, en la formació doctoral i la generació de noves oportunitats territorials.

Al llarg d'aquest període s'han inscrit més d'un centenar de tesis doctorals (s'ha format a 69 doctors i doctores, i 35 tesis es troben actualment en curs) que han estat dirigides per una cinquantena de doctors i doctores. Del centenar de tesis inscrites, el 40% han estat elaborades per dones. Així el programa de doctorat contribueix a revertir el desequilibri de gènere existent en un àmbit com el de les enginyeries altament masculinitzat.

Així mateix, el programa ha consolidat una capacitat d'atracció de talent internacional, provinent de múltiples països europeus així com d'Amèrica i Àsia. Més d'un 30% de les tesis inscrites han estat dutes a terme per persones amb nacionalitat estrangera.

El repte mediambiental és global en múltiples esferes, i en aquest sentit, el programa ha consolidat el seu caràcter multidisciplinar, capaç de generar impacte positiu en múltiples i diversos àmbits amb més de 100 publicacions. Entre el conjunt de tesis inscrites destaquen com a matèries l'enginyeria química ambiental, l'enginyeria minera, la contaminació atmosfèrica, la geologia i la geoquímica, entre d'altres.

Prova d'aquest caràcter multi i interdisciplinar és la diversitat de línies d'investigació en marxa. El programa de doctorat disposa actualment dels següents grups d'investigació:

- BIOGAP - Grup de Tractament Biològic de Contaminants Gasosos i Olors.
- CIRCUIT - Grup de Recerca en Circuits i Sistemes de Comunicació.
- EXPLORATORI - EXPLORATORI dels Recursos de la Natura.
- GREMS - Grup de Recerca en Mineria Sostenible.
- RIIS - Grup de Recerca en Recursos i Indústries Intel·ligents i Sostenibles.
- SSR-UPC - Centre específic de recerca Smart Sustainable Resources.

El llibre vol ser un reflex de tota la tasca investigadora duta a terme al llarg de tots aquests anys. S'estructura en tres grans apartats que incorporen un resum gràfic i històric de l'impacte generat pel programa, una explicació detallada de l'àmbit d'estudi i treball dels sis grups de recerca; i finalment, els resums acadèmics del centenar de tesis doctorals inscrites, aquelles que ja han estat llegides i les que actualment es troben en elaboració.

Al final del document en forma d'índex d'autories es poden consultar totes les persones investigadores que amb esforç al llarg d'aquests 30 anys han contribuït a consolidar el programa, i que amb les seves tesis doctorals han pogut buscar i trobar respostes a problemes i necessitats en l'àmbit mediambiental i dels recursos naturals. Volem agrair especialment a totes elles, i als directors i directores de tesis que amb les seves aportacions han fet possible aquest llibre esdevenint un merescut homenatge que permet apropar l'activitat del programa de doctorat al conjunt de la ciutadania.

La publicació ha estat coordinada per part de la Comissió Acadèmica del programa de doctorat en Recursos Naturals i Medi Ambient. Ha comptat amb la col·laboració de la Universitat Politècnica de Catalunya i la Biblioteca del Campus Universitari de Manresa (BCUM-UPC), i d'institucions i agents del territori: el Consell Comarcal del Bages, l'Ajuntament de Manresa, PIMEC Catalunya Central, Cambra de Comerç de Manresa i Eurecat, als qui també agraïm enormement el seu suport i col·laboració.

Doctorat en Recursos Naturals i Medi Ambient (1992-2022)

69 TESIS LLEGIDES

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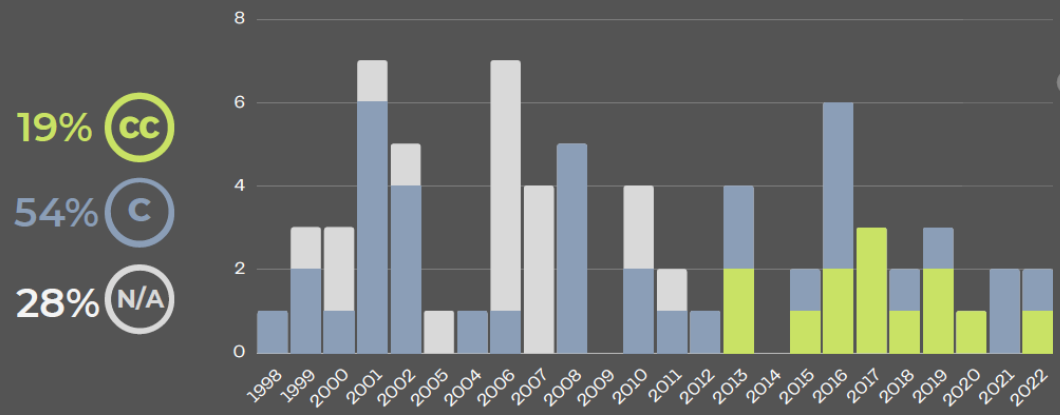

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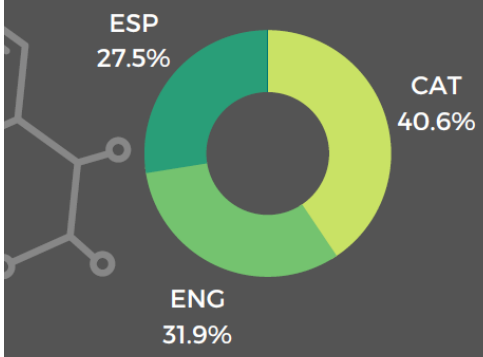
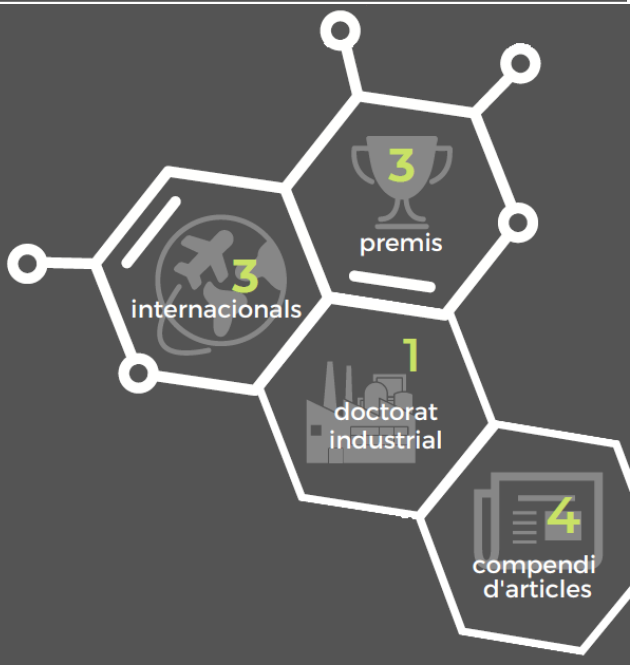
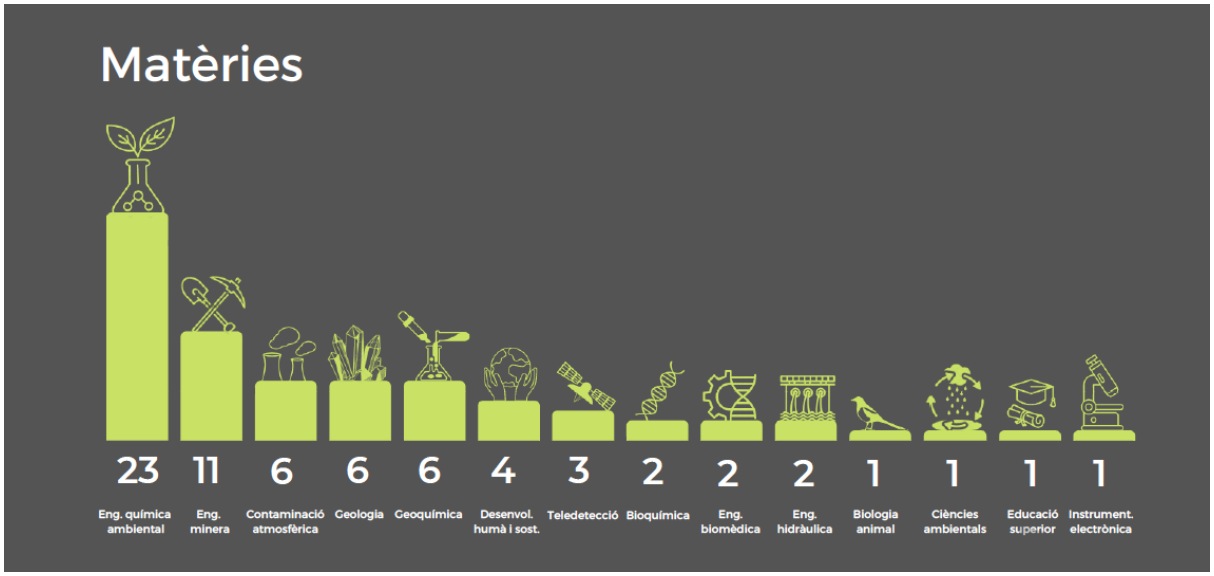
Gènere

Idioma







RESEARCH LINES

The society of the 21st century requires technologies that allow an optimal use of natural resources, maintaining at all times a respectful attitude towards the environment and sustainability criteria. The Doctoral Program carries out its research in the field of the use of available natural resources under the prism of minimizing their environmental impact. This perspective is considered from a holistic point of view, which includes all environmental aspects, from obtaining the raw material to its deposition once converted into waste, including all the stages related to its physicochemical and biological transformation. In this framework, the PhD Program in Natural Resources and Environment is based on the set of research lines of 6 research groups (BIOGAP, CIRCUIT, ERN, GREMS, RIIS and SSR). The program responds to the challenge of optimal utilization of natural resources and urban, industrial and mining waste from a comprehensive and multidisciplinary perspective. Bearing in mind that resources are limited, it focuses its activity on the search for solutions to minimize the production of waste or achieve its utilization under the guidelines promoted by the European Union, of Zero Waste and Circular Economy.

BIOGAP - Biological Treatment of Gaseous Pollutants and Odours Group

Francesc Xavier de las Heras, Antonio David Dorado, Xavier Gamisans[1], Xavier Guimerà, Conxita Lao, Montserrat Solé

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Keywords: Biofiltration, bioleaching, circular bioeconomy, modeling, gaseous pollutants, WEEE.

In recent years, the UPC's research group on biological treatment of gaseous pollutants and odours (BIOGAP) has become a benchmark in the application of biological techniques to solve a wide range of environmental problems. Thus, the group already has extensive experience in the use of bio-based processes for the treatment of different types of organic and inorganic gaseous pollutants as well as in the characterization of these devices both from a theoretical (tailored and/or advanced modelling using CFD techniques) and practical point of view (design and construction of pilot plants/prototypes, microbial activity assessment through respirometric techniques, biofilm monitoring using ad hoc designed microsensors, among others). Also, the development of combined physical-chemical-biological processes for metals recovery from different solid wastes is part of the know-how of the Group.

BIOGAP members have strong experience in the application of science and engineering concepts in order to offer solutions based on the circular (bio)economy concept. In this sense, the group has experienced in recent years a paradigm change, moving from “treatment” or wastes from different sources (mainly gaseous and solid), to “resources recovery”.

As examples of this new paradigm, the BIOGAP research group has developed technologies for:

- Biogas upgrading including raw materials recovery: desulfurization with elemental sulfur production
- Recovery of valuable metals from waste electric and electronic equipment (WEEE): copper recovery from PCBs
- Use of hydrogen-mediated bioprocesses for gaseous emissions valorization: production of methane from carbon dioxide emissions

The group has extensive experience in the management of public and private projects and, in general, in knowledge transfer. Main funding agencies are: the Spanish Government (Agencia Estatal de Investigación), the Catalan Government (ACCIÓ-Agència per a la competitivitat de l'empresa) and the European Union (LIFE programme).

Finally, it is worth mentioning the international projection of the group, which is reflected with different collaborations (research projects and joint publications) in USA, Mexico, Netherlands, Germany, Greece, Italy, France, Belgium among others.

Main contributions

- Caracterización de biopelículas y herramientas avanzadas de modelización para el desarrollo de bioreactores mediados con hidrógeno para la valorización de gases residuales. Gamisans X.; Solé, M.; Bonsfills, A.; Castro, R.; Guimera, X. Competitive Project. Agencia Española de Investigación. (2022-2025)
- Bioprocés per a la recuperació de cobalt i liti en bateries. Dorado, A.D.; Gamisans, X.; Guimera, X.; Lao, C.; Solé, M. Competitive Project. ACCIÓ-Generalitat de Catalunya. (2021-2024)
- Sustainable biogas purification system in landfills and municipal solid wastes treatment plants. Dorado, A.D.; Gamisans, X.; Lao, C; Solé, M. Competitive Project. EU-LIFE Programme. (2019-2023)
- Método para recuperación biológica de metales en residuos eléctricos y electrónicos. Dorado, A.D.; Benzal, E.; Gamisans, X.; Sole, M.; Lao, C. Industrial Property. (2021)
- Eliminación de altas cargas de amoníaco en efluentes gaseosos mediante tecnologías biológicas optimizadas. Dorado, A.D.; Gamisans, X. Non-competitive Project. ECOTEC Ecología Técnica S.A. (2017-2019)

CIRCUIT - Communication Circuits and Systems Research Group

Francesc Xavier Moncunill Geniz[1], Víctor Barcons Xixons, Jordi Bonet Dalmau, Francisco del Águila López, Ilker Seyfettin Demirkol, Josep Font Teixidó, M. Rosa Giralt Mas, Pere Palà Schönwälder, Marta Isabel Tarrés Puertas, Sebastià Vila Marta

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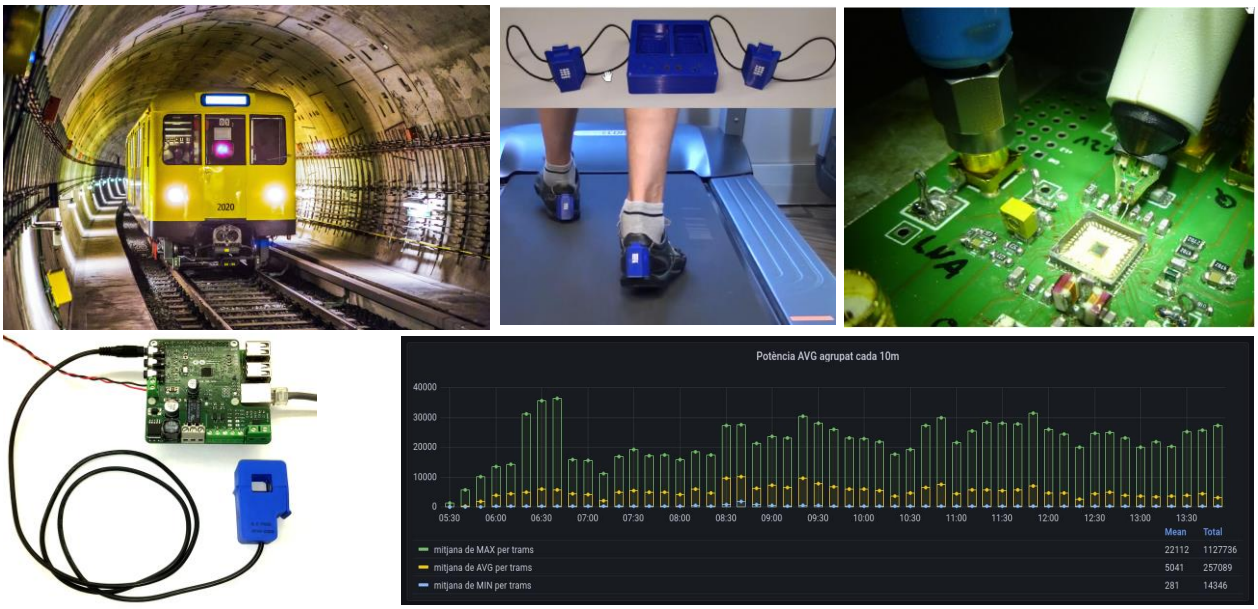

The Communication Circuits and Systems Research Group (CIRCUIT) has a track record of more than 20 years in research and knowledge transfer in the field of information technology, communications and electronics.

Circuits and Systems for Communications

The group has been involved in the use and development of CAD techniques for the analysis and design of electronic circuits, including switched circuits, variant circuits, nonlinear circuits and distributed parameter circuits, as well as stability and bifurcation analysis. CIRCUIT has participated in seven research projects funded by the Spanish government related to the development of low-energy and low-cost wireless communication systems. In these projects, new architectures of communication receivers and transceivers have been proposed, and several prototypes have been designed and fabricated in CMOS technology. The group also has experience in the use of advanced signal modulation techniques such as spread spectrum, ultra-wideband and OFDM modulations. Currently, it is developing a wake-up radio solution for 5G mobile devices.

Internet of Things and Industry 4.0

In connection with the ICT Systems Engineering degree, in which the group teaches, it has gained experience in systems engineering and systems integration, embedded systems, low-

consumption processing techniques and programmable devices, intelligent sensor and ad-hoc networks, Internet of Things (IoT) and 5G technologies.

The group has participated in the Looming Factory Alliance activities (https://loomingfactory.upc.edu/looming-factory) and is a member of XaFIR (Xarxa Fourth Industrial Revolution, https://xafir.cat), both devoted to promote the implementation of Industry 4.0 in Catalonia. Examples of use cases, many of them developed in the context of technology transfer agreements, include:

- Vibration monitoring in industrial machines (e.g., numerical-control milling machines) and in railway tracks (traffic, wear of supports, rails and wheels);
- Remote monitoring of electric energy generation and consumption systems;
- Remote activity monitoring of machines in textile workshops and of water pumps in water management companies;
- Wearable system for the monitoring of environmental conditions of workers (temperature, humidity, vibrations, noise, position) in factories and in mining;
- Wearable system for human gait monitoring (workers' activity, disease detection, rehabilitation support);
- Sensors to detect falls of elderly people;
- UCI bed inclinometer;
- Monitoring systems for mining drilling and blasting.

Main contributions

- Advances in ultra-low-power wireless communications and their application to continuous human gait monitoring. Palà, P.; Moncunill, X.; Bonet, J.; del Águila, F.; Giralt, R.; Vila, S.; Tarrés, M.; Sanz, M.; Escobet, T.; López, A. Competitive Project. Ministerio de Economía Y Competitividad (2016-2019).
- Agrupació Emergent Looming Factory. Moncunill, X.; Bonet, J.; del Águila, F.; Arumí A. Competitive Project. Generalitat de Catalunya. Departament d'Empresa i Coneixement (2019-2022).
- Fourth Industrial Revolution Network (XaFIR). Moncunill, X.; Bonet, J.; del Águila, F.; Arumí A. Competitive Project. Agència de Gestió d'Ajuts Universitaris i de Recerca (AGAUR) (2020-2022).
- Desenvolupament d'un sistema micro-electromecànic per a la digitalització de perforacions. Palà P.; Bascompta, M.; Bonet, J. Competitive Project. Agència de Suport a la Competitivitat de l'Empresa Catalana (ACCIÓ) (2020-2022).
- Pushing the Limits of Energy Efficiency in Mobile Devices through Wake-Up Radio Solutions. Demirkol, I.; Moncunill, X.; Paradells, J.; Palà, P.; Bonet, J.; Aguila, F.; Pupiales, C. Competitive Project. Agencia Estatal de Investigacion (2022-2025).

ERN – EXPLORATORI of Natural Resources

M. Dolors Grau Vilalta[1], Jordi Cunill Solà, Lorena Mulero Jiménez

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Keywords: Natural resources, Sustainability, Secondary School, STEAM

The main objective of the EXPLORATORI of natural resources (EXPLORATORI) is to bring science and technology closer to secondary school students, their teachers and the society in general, by using the sustainable use of natural resources as a backbone. The activities organized are classified in several projects:

EXPLORE Courses

Addressed to science and technology teachers in Secondary level education (30 editions). The purpose is to provide tools for teachers to be used afterwards in their lectures with students. The singularity consists in the combination between the theoretical lectures with sessions of learning by doing and field visits.

Knowledge Fair

It is a two-day Science Communication Event (9 editions). The aim is to introduce the science and technology research projects held in UPC university (9 research groups), to young people. Two PhD students present their research. The close age between them allow providing participants with an enriching exchange of their academic experiences.

Catalunya Young Talent FORUM

The best 40 students of Catalunya (15-16 years old) are awarded during 4 days working with prominent figures and scientist (8 editions). The central topic is different in each edition. On the last day they present their conclusions in groups in abstract graphics format in the presence of their families.

SAVEnergy Project

The aim of this project was saving energy in the homes of secondary school students. It was awarded by the Government with the “Premi Medi Ambient 2017”.

Forest and sustainability Project

It is a citizen science project that seeks to transmit the importance of sustainably managing forests studying their relationship with the SDGs of the Agenda 2030. The participating students collect data from their own cities and counties about quality water and air, and the state of tree cover. Simultaneously, they evaluate their own consumption of water and energy. 60 Secondary schools of Catalunya took part in the project.

The EXPLORATORI activities are included in different networks: In Catalunya, the activities are recognized by the Plan of continuous teacher training of the Department of Education of the Government and recognized by STEAMcat initiative. Also included in “Educació del demà”-Fundació Jaume Bofill, and in the STEMARIUM platform-Fundació Catalana per a la Recerca i la Innovació. In UE, the project is included in the platform SCIENTIX (The Community for Science Education in Europe) and in SDSN (Sustainable Development Solutions Network).

Main contributions

- El Bosque y la sosternibilidad. Grau, M.D.; Cunill, J; Mancho, F.; Mulero, L. Domenjó, I. Projecte R+D+I competititu: FECYT
- Young students as critical science detectives. Grau, M.D.; Torra, I.; Mancho, F.; Mulero, L.Projecte R+D+I competititu: Erasmus+
- Open Science Schooling: Grau, M.D.; Torra, I.; Mancho, F.; Mulero, L.Projecte R+D+I competititu: Erasmus+
- ScienceGirls:¡Sí a la ciencia y a la tecnología! Grau, M.D.; Torra, I. Projecte R+D+I competititu: FECYT
- ScienceGirls: Teenage girls as co-creators of science learning engagement. Grau, M.D.; Torra, I.; Font, J.; Sabata, M.; Jodar, M. Projecte R+D+I competititu: Erasmus+

GREMS - Sustainable Mining Research Group

María Pura Alfonso Abella, Marc Bascompta Massanes, Jose Juan de Felipe Blanch, Carlos Hoffmann Sampaio, Maria Niubó Eslava, Josep Oliva Moncunill, David Parcerisa Duocastella[1], Maria Dolores Riera Colom, Lluis Sanmiquel Pera, Jordi Vives Costa, Maria Teresa Yubero De Mateo, Hernan Anticoi Sudzuki, Francesc Pérez Ràfols

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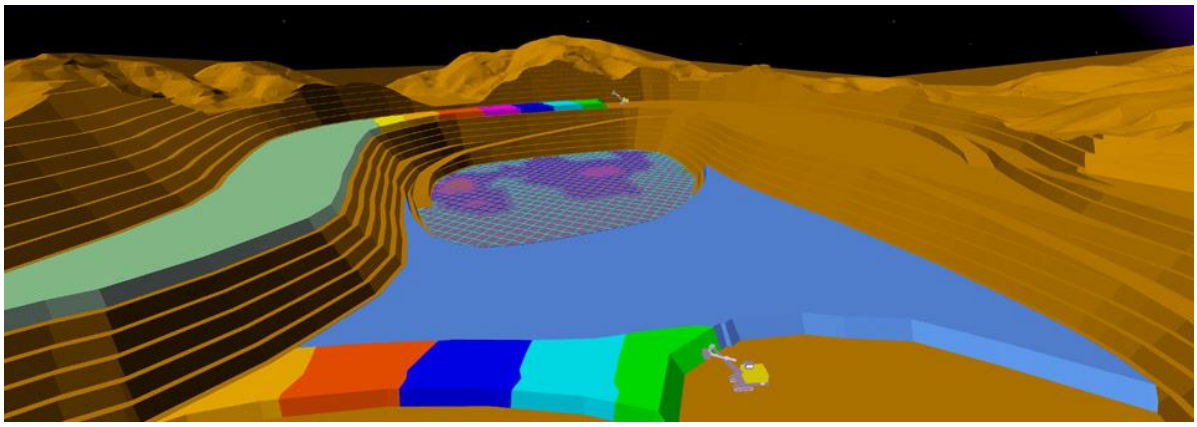
Keywords: mineral deposits, mining, smart mining, circular economy, urban mining, recycling, subsidence, underground environments, geological and mining heritage.



The main research topics of the Sustainable Mining Research Group (GREMS) focus on the field of mining, the key development and consolidation strategies are detailed below:

Characterization of mineral deposits

This research topic aims to characterize the genesis of mineral deposits around the world based on the study of the petrology and geochemistry of the minerals forming the deposit. Another investigation in this research topic deals with the development of geostandard minerals in order to be used as a correction factor in geochemical analysis techniques of minerals, particularly in solid solutions such as feldspars or carbonates.

Optimization in the processing of minerals

This research topic has taken on a special prominence during the last years of the research group's activity. The main research that is carried out in this area deals with the optimization of the grinding and separation processes of all types of minerals in both rocks and waste. The consolidation of a mineral processing laboratory within the UPC Manresa and the contact with prestigious researchers from the main Mining Schools in Europe and with companies in the sector at the international level has determined the growth of this research topic.

Subsidence control, safety and environmental conditions in underground settings

This research topic is led by Dr. Lluís Sanmiquel, a member of the research group, and developed within the framework of the collaboration with the mining company ICL. This research makes high-precision calculations of subsidence using interferometry. Work is also being done on the modelling of subsidence based on the geological and geomechanical analysis of the terrain and on the modelling of the ventilation conditions of underground settings.

Preservation of geological and mining heritage

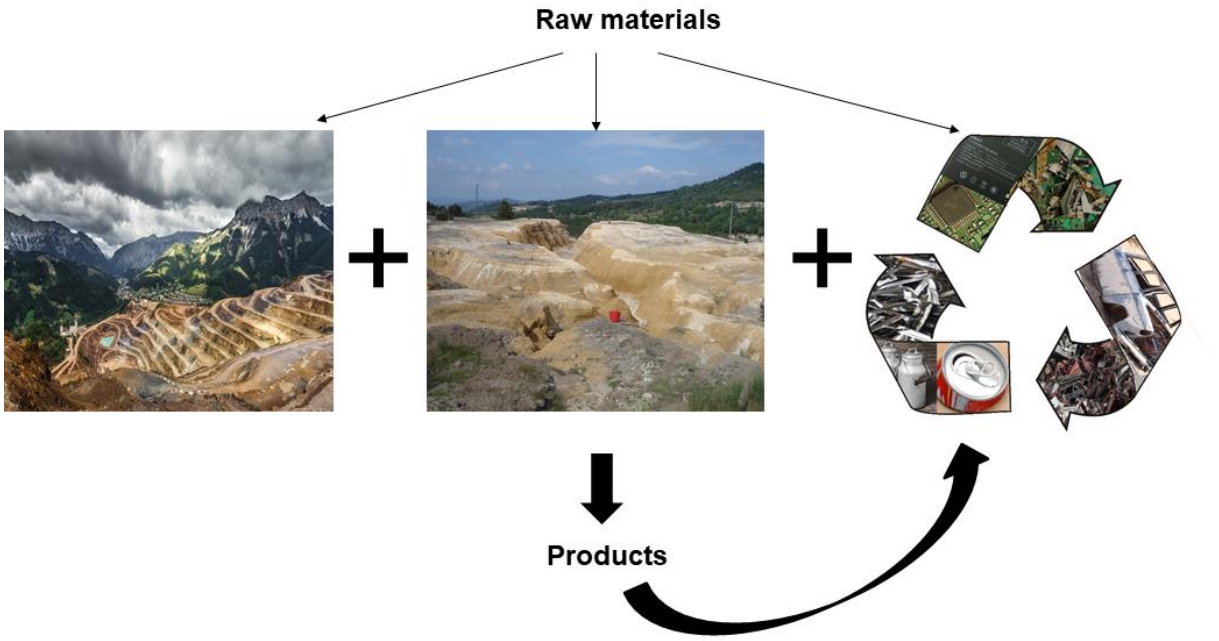
Some of the researchers in the research group collaborate with the UNESCO Geopark of Central Catalonia working on the preservation of the geological and mining heritage of Catalonia and, specifically, in the territory of the Geopark.

Main contributions

- Projecte nacional competitiu Recerca en processos per separar els components de la fracció mineral dels residus de construcció i demolició. Oliva, J.; Hoffmann, C.; Alfonso, P.; Anticoi, H. (2021-2024)
- Projecte nacional competitiu Desenvolupament d'un sistema micro electromecànic per a la digitalització de perforacions. Palà,-Schönwälder, P.; Bascompta, M.; Bonet-Dalmau, J. (2020-2022)
- Projecte nacional competitiu Valorización de residuos de chapa de titanio para la fabricación de polvo metálico por atomización. Riera, M. (2020-2022)
- Projecte nacional competitiu Modelització i desenvolupament d'un nou procés per a la purificació del CaCo3. Parcerisa, D.; Oliva, J.; Bascompta, M.; Hoffmann, C.; Alfonso, P.; Anticoi, H.; Sidki, N.; Reverté, M. (2019-2021).
- Projecte europeu competitiu OptimOre (H2020-642201). Oliva, J.; Alfonso, P.; Anticoi, H.; Guasch, E.; Sanmiquel, L.; Parcerisa, D.; Escobet, T.; Hamid, S.; Escobet, A.; de Felipe, J.J.; Argelaguet, M.; Bascompta, M.; Jorge, J.; Alvarez-Rodriguez, B.; Peña-Pitarch, E.; Bergas, J.; Chugunova, M. (2014-2018).

RIIS - Intelligent and Sustainable Resources and Industries Research Group

Keywords: sustainability, raw materials, mining wastes, urban wastes, 4.0 industry



The Intelligent and Sustainable Resources and Industries Research Group (RIIS) was created as an opportunity to carry out research with a transversal approach that enables it to deal with challenges at different stages. This facilitates to carry out research projects prepared to provide sustainable and integrated solutions for the use of natural resources and urban, industrial and mining waste by means of technologies for the localisation, characterisation, processing, optimisation and reuse of these resources.

The objectives of the RIIS group are to do research to contribute to a sustainable use of resources, whether natural or from recycling, by approaching their study from a transversal perspective (prospecting and mining exploitation, physical, chemical and biological treatment of resources, use of technologies for the collection and interpretation of information through sensing, communication networks and data processing).

The RIIS has joined three previous research groups constituted by members of the Department of Mining, Industrial and ICT Engineering of the Polytechnic University of Catalonia (UPC). The RIIS works to provide a comprehensive solution to the generation and reduction of waste through treatment for its optimal use, contributing to the trend towards zero waste and the circular economy. These integrated solutions require different fields of action. The research to be

developed deals with the use of mineral resources, use of urban, industrial and mining wastes, conventional, urban and industrial smart and sustainable mining and ICT health and Industry 4.0.

The RIIS is made up of 28 researchers, all of them staff of the UPC at Manresa. In addition, the group has a large number of collaborators, including young researchers who are working on their doctoral thesis or are associate professors. The existence of these members is important for the group to continue its trajectory and even grow.

The group is structured in three lines established on the basis of the different specialities of its members and which coincide with the three research groups recognised by the Agency for Management of University and Research Grants (AGAUR), these are BIOGAP: Biological Treatment of Gaseous Contaminants and Odours Group, CIRCUIT: Research Group on Circuits and Communication Systems and GREMS: Research Group on Sustainable Mining.

To achieve the objectives, the researchers that make up the RIIS come from different research fields to provide an advanced knowledge in the different aspects needed to optimise the planet's resources, such as the location and characterisation of mineral deposits, the efficient use of these resources, the use of enabling technologies such as biotechnology for the use of all types of resources (mineral, industrial and urban), and the application of advanced monitoring and data processing systems to ensure efficient, sustainable and intelligent use of resources.

SSR-UPC – Smart Sustainable Resources

Pura Alfonso, Víctor Barcons, Marc Bascompta[1], Jordi Bonet-Dalmau, Francesc Xavier de las Heras, Francisco del Águila, Ilker Demirkol, Antonio David Dorado, Jose Juan de Felipe, Josep Font, Xavier Gamisans, Rosa Giralt, Xavier Guimerà, Carlos Hoffmann, Conxita Lao, Joan Antoni López, Francesc Xavier Moncunill-Geniz, María Niubó, Josep Oliva, Pere Palà, David Parcerisa, Francesc Pérez, Maria Dolors Riera, Lluís Sanmiquel, Montserrat Solé, Marta Isabel Tarrés, Marc Vallbé, Sebastià Vila, Jordi Vives, María Teresa Yubero

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Keywords: mining, sustainability, smart mining, natural resources, circular economy, urban mining, sensor networks, intelligent systems, information processing, industry 4.0, recycling.

The SSR-UPC Tecnio centre responds to the needs of society towards a more efficient and sustainable use of natural resources, applying technologies for the localisation, processing, optimisation and reuse of these resources. In this sense, the centre's lines of work are linked to the PhD programme in Natural Resources and the Environment in the following areas:

Use of mineral resources

Locate and characterise mineral deposits and find techniques to optimise their processing, minimising the energy consumption and increasing the use of the resources.

Use of urban, industrial and mining waste.

Localise and characterise waste, promoting efficient and sustainable techniques based on biological processes, reincorporating the waste into the system and promoting the circular economy.

Smart mining.

Develop automation and smart sensing systems, both in resource extraction processes and in the processing of minerals.

Intelligent and sustainable urban and industrial mining.

Inclusion of sensor networks for the recovery of raw materials from urban and industrial waste.

Transfer of knowledge to the industrial sector.

Promote the incorporation of the results in any public or private institution.

Projection to society.

Raise society's awareness of the use of mineral resources and recycling, as well as their necessity for the energy transition and the circular economy.

DOCTORAL THESES IN PROGRESS

Doctoral Theses being developed in the
Program of Natural Resources and Environment (2023 - 2024)

Fast track to cleaner urban aerosols in public transport environments

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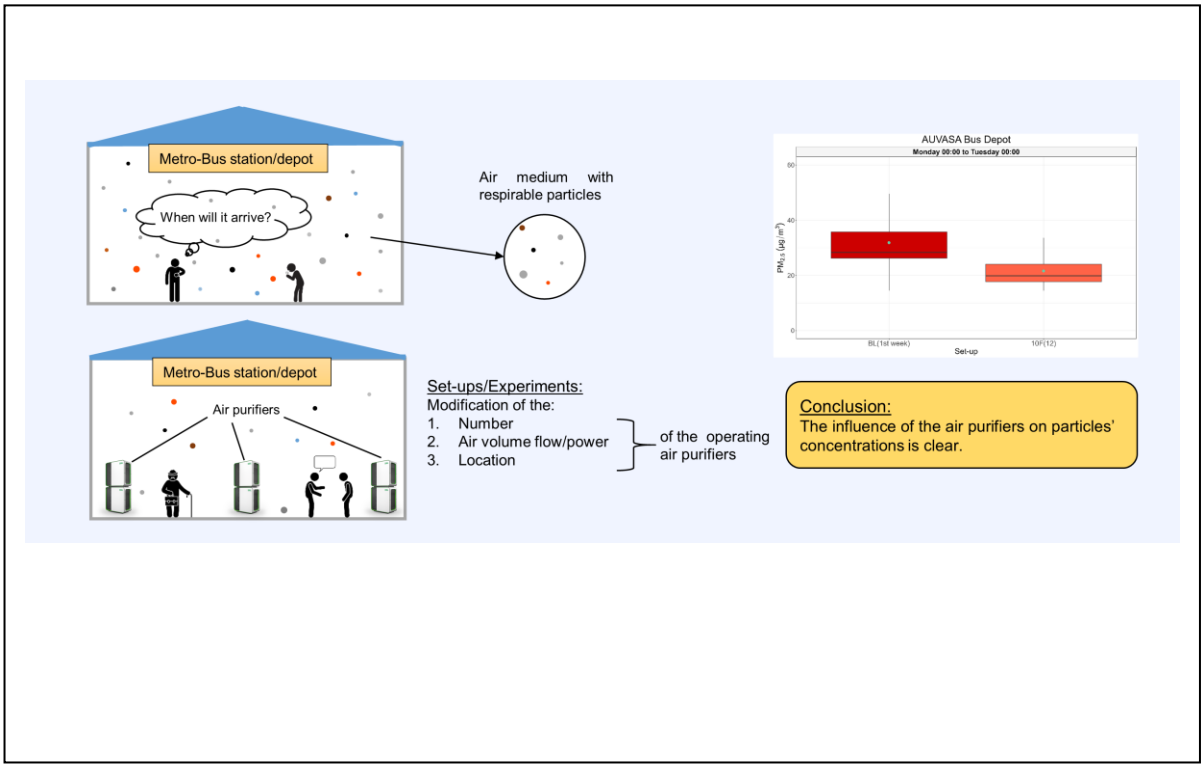
Keywords: Air quality, bus station/depot, metro station, air purifiers, human health,

Graphical Abstract



In metropolitan areas, buses and subway systems are two of the most common forms of transportation and people spend a significant amount of time commuting through them. However, even if politicians try to encourage people to use more public transport, studies demonstrate there is poor air quality in buses, metros, and their stations as the concentrations of respirable particles are high, and usually higher than those in the outdoor environment (e.g. Martins et al.,

2015; Betancourt et al., 2019). The concentrations of particles vary from metro station to metro station and from bus station to bus station. This happens due to the combination of several factors which affect air quality in such (semi-)closed environments (e.g. design of the station, train/bus frequency etc.).

It is well known that particulate matter can cause, or at least contribute, to adverse effects on human health, and consequently lead to reduced life quality and expectancy (Kim et al., 2015). Nevertheless, no legislation or a viable solution exists until now to limit passengers' exposure at bus and metro stations.

The issue of not having viable retrofit solutions to minimize the existing high concentrations of particles in environments such as bus stations/depots and metro stations, made the EU to initiate a call for such solutions which led to the creation of **A**ero**S**ol**fd** project [fast track to cleaner, healthier urban Aerosols by market ready Solutions for tailpipe, brake systems and (semi-)closed environments of retrofit Filtration Devices]. One of the retrofit solutions that **A**ero**S**ol**fd** aims to provide, is to use stationary air purifiers specifically designed for (semi-)closed environments.

The first aim of this study is to characterize passengers and workers' exposure at PM (mass, number and chemical composition) and BC in a bus depot and two metro stations and compare them with those of other stations/depots throughout the world. The second aim is to demonstrate the impact of stationary air purifiers on the measuring parameters inside the aforementioned (semi-)closed environments. Consequently, $PM_{2.5}$ and BC mass concentrations, as well as particle number concentrations (PN, 10 nm – 10 μm) were measured and analyzed before and during the operation of the abovementioned air purifiers. For comparative reasons, $PM_{2.5}$ concentrations and meteorological parameters of the outdoor environment were also studied.

Each measurement campaign lasts for at least one month. One measurement campaign was done for each measurement location, with the exception of the bus depot where two campaigns took place. As a general principle, continuous baseline measurements (BL, i.e. without using air purifiers) were and will be obtained the 1st week of each campaign to assess the levels and distribution of the measurement parameters at the study areas. The rest period of time, measurements were, and will be, obtained by experimenting with the air purifiers. In other words, different experiments were and will be made by modifying the number, the air volume flow/power and the location of the operating air purifiers. The study areas, which are located in Europe, are AUVASA bus depot (Valladolid, Spain), Lisbon Metro (Lisbon, Portugal) and Sofia Metro (Sofia, Bulgaria). With the exception of Sofia Metro, which measurements will take place the following months, all the measurement campaigns have been completed.

The preliminary results show much higher $PM_{2.5}$ concentrations in the studied (semi-)closed environments compared to those in the outdoor environment. The concentrations of $PM_{2.5}$ in the bus depot do not vary a lot from those of EU permissible limits for the outdoor environment (25 μg/m^3), whereas $PM_{2.5}$ concentrations in Lisbon Metro are much higher than 25 μg/m^3. Lisbon Metro platform also demonstrated much higher number concentrations of particles compared to those in the bus depot. AUVASA bus depot and Lisbon Metro illustrated a specific $PM_{2.5}$ temporal distribution. These differences could be related with the differences between the semi-closed

environments (i.e. public restricted bus depot vs metro station, different air pollutant sources), their different design, their ventilation systems, their daily operation/shifts, the frequency of the trains/buses, the composition of their wheel and brake pads and the outdoor air quality. During the function of the air purifiers, lower $PM_{2.5}$ mass concentrations and number concentrations of particles with a diameter between 0.3 and 10 µm and $PM_{2.5}$ were clearly observed. Nevertheless, the impact of the air purifiers on smaller particles and black carbon was not clear. In relation to the chemical composition, particles are expected to show specific chemical elements (e.g. Fe, Cu, Ba etc.).

Acknowledgment:

Authors express appreciation to the European Union for funding this Horizon program by [101056661 = AeroSolfd].

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Research in processes to separate the components of the mineral fraction of construction and demolition waste

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Keywords: CDW, Contaminant, Jigging, Recovery, Sustainability

The management of construction and demolition waste (CDW) is a significant challenge in the modern era. CDW is one of the largest and heaviest waste streams generated globally, particularly in the European Union (EU). CDW encompasses waste generated from the construction, extension, reconstruction, demolition, and maintenance of buildings and infrastructure. In the EU, the demolition and construction industries produce approximately 900 [1] million tons of CDW annually, with an increasing trend each year. The EU Waste Framework Directive (2008/98/EC) mandates member states to achieve a minimum recycling target of 70% by 2020, with varying success across different countries.

The primary objective of the project is to develop a technological solution that enables the valorization of the mineral fraction of CDW, achieving recovery rates exceeding 90%. This involves investigating new processes to separate materials in the mineral mixture of CDW, resulting in new products [2]. The project aims to enhance circular economy practices by improving the efficiency of resource use and producing high-quality recycled materials for the construction industry.

Initial studies indicate that current CDW recycling plants primarily crush and separate lightweight materials and metals, leaving mixed constituents like concrete, bricks, and ceramics, which limits the quality of recycled materials. This project aims to overcome these limitations by effectively separating these constituents and enhancing their value. The project will also advance knowledge in CDW recycling through detailed studies and characterization, addressing significant technological challenges and ensuring effective separation.

There is a growing recognition of the potential benefits of incorporating recycled CDW materials into construction activities. Richardson [4] highlights the promising prospect of utilizing coarse recycled aggregates in new concrete formulations to address waste generation concerns and meet escalating demand for construction materials. This approach not only helps alleviate environmental burdens associated with waste disposal but also contributes to resource conservation and circular economy principles.

Main preliminary conclusions:

- **Magnitude of CDW Generation**: The data reveal that the construction and demolition industries generate a substantial volume of waste, estimated at around 900 million tons annually in the European Union. This highlights the urgent need for effective waste management strategies to mitigate environmental impacts and promote resource conservation.
- **Challenges in CDW Utilization**: While CDW presents opportunities for reuse in various applications, including concrete, mortar, ceramics, and asphalt, challenges such as the presence of contaminants significantly impact its suitability for recycling. Contaminants can negatively affect the properties of recycled aggregates, limiting their potential for integration into construction processes.
- **Importance of Separation Technologies**: Effective separation technologies, such as comminution, sieving, and jigging, play a crucial role in extracting valuable materials from CDW for reuse. These processes enable the segregation of constituents based on size and density, facilitating the recovery of high-quality recycled aggregates with enhanced usability.
- **Promising Solutions for CDW Management**: Despite the challenges, there are promising solutions for managing CDW, including the utilization of coarse recycled aggregates in new concrete formulations. This approach not only addresses waste generation concerns but also contributes to resource conservation and circular economy principles.
- **Opportunities for Innovation**: The findings highlight opportunities for innovation in CDW management, particularly in the development of efficient separation processes and the characterization of recycled materials. By harnessing innovative technologies and best practices, stakeholders can maximize the value and utility of recycled CDW materials, advancing towards a more sustainable built environment.

Acknowledgement:

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Assessing water use efficiency in Catalonia with DEA approach

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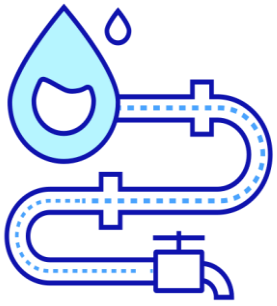
Keywords: DEA, Efficiency, GDP, water

Graphical Abstract

Summary: Evaluating the efficiency of water use in Catalonia using DEA, focusing on industrial and domestic water consumption as inputs and GDP as output.

Region **Input: Water consumption** **Output: GDP**



Methodology

Data Envelopment Analysis (DEA) is a non-parametric method using linear programming to measure the efficiency of decision-making units (DMUs) by comparing them to a production frontier. DEA models like CCR and BCC assess efficiency under various scale assumptions and can be input- or output-oriented.

DEA Model

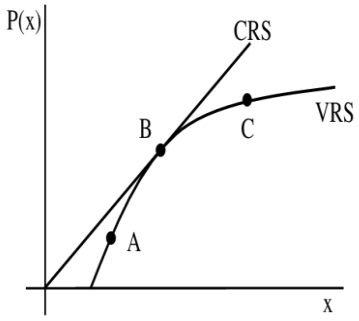


table 1. Descriptive statistics of the parameters

Variable	Parameter types	Units
Industrial water consumption	Input	m^3
Domestic water consumption	Input	m^3
Total water consumption	Input	m^3
Gross domestic product (GDP)	Output	millions of euros

Result:

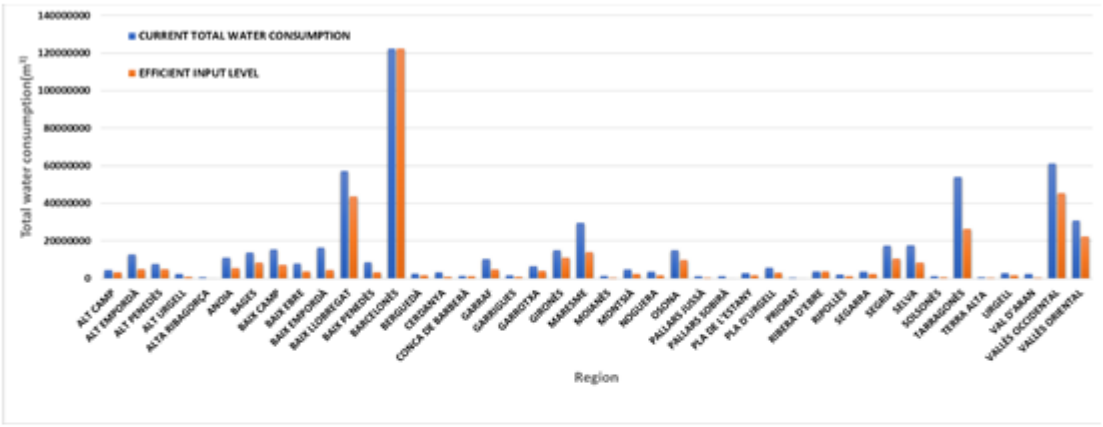
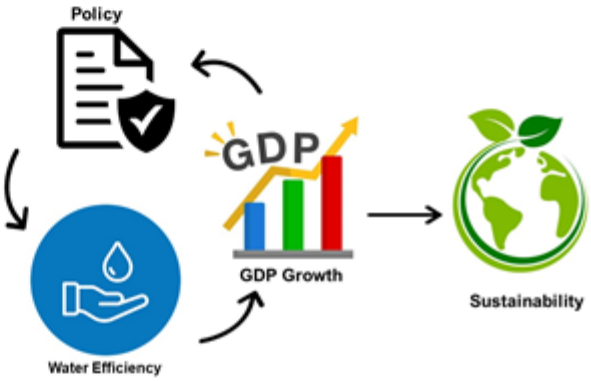


Figure 1. Comparative analysis of industrial and domestic water consumption: current input levels vs. efficient input levels with constant GDP output

Full Efficiency

Conclusion



Conclusion:

Results highlights the importance of sustainable water management, showing Barcelona and Ribera D'Ebre as benchmarks of efficiency in Catalonia. Leveraging insights from these regions can guide improvements in water use efficiency, aligning with global sustainability goals and catalyzing economic growth.

Acknowledgment:

Special thanks to Ms. Haniyeh Zavarogh for her support.

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Abstract

Water scarcity is a pressing global issue, worsened by factors like climate change and population growth, particularly affecting arid regions. Rapid economic development and urbanization exacerbate water demand, straining resources and hindering socioeconomic progress. Improving water use efficiency (WRUE) is vital for sustainable development.

Studies globally, such as those by Speelman et al. (2008), Bian et al. (2014), Ren et al. (2017), Wang et al. (2018), Geng et al. (2019), and others, have utilized Data Envelopment Analysis (DEA) to evaluate WRUE, offering insights into policy improvements and resource management strategies.

In Catalonia, facing water scarcity amid economic growth, research on WRUE remains limited. This study aims to address this gap by assessing WRUE in relation to GDP growth, utilizing DEA models. The findings seek to inform sustainable water management strategies and policy decisions, facilitating both economic growth and environmental conservation.

DEA is a versatile method for evaluating efficiency without relying on specific production function assumptions. It compares production units based on their input-output relationships, generating efficiency scores ranging from 0 to 1.

DEA offers Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) models. CRS assumes proportional input-output variations, while VRS allows for variable scale efficiency. This distinction between Pure Technical Efficiency (PTE) and Scale Efficiency (SE) provides insights into optimal production scale.

Efficiency scores (TE) reflect the percentage reduction in inputs, with SE indicating the impact of scale size on productivity. Both CRS and VRS DEA models were used in this study, analyzed with the DEAP program.
Figure 1 compares current and efficient input levels (total water consumption) while maintaining GDP output constant. The goal is to illustrate opportunities for resource efficiency improvement to stabilize economic output. The chart includes representations of current and efficient input levels obtained from the DEA model, serving as benchmarks for maximum efficiency. Observations inform units about potential areas for improvement in resource utilization. Deviations from efficient input levels indicate optimization opportunities without compromising output stability. Decision-makers can use the chart to compare input levels and align them with efficiency benchmarks, enhancing resource efficiency and economic output stability. This provides practical insights for optimizing input levels and promoting economic stability.

In conclusion, our analysis of water use efficiency in Catalonia reinforces the crucial need for sustainable resource management, consistent with previous research. Barcelona's operational efficiency serves as a benchmark, echoing findings from studies by Speelman et al. (2008) and Bian et al. (2014). Ribera D'Ebre exhibits full efficiency, aligning with studies by Ren et al. (2017) and Wang et al. (2018), highlighting the importance of optimizing resource utilization.

Insights from Ribera D'Ebre can guide other units toward efficiency, mirroring findings from Terra Alta, Priorat, and Barcelonès, resonating with research by Hsieh et al. (2019) and Geng et al. (2019) on improving allocative efficiency.

Considering both domestic and industrial water consumption as inputs and GDP as output, Ribera D'Ebre and Barcelona demonstrate full efficiency, reflecting consistent findings from various studies. Understanding VRS scores and Lambda values is crucial for enhancing operational effectiveness and sustainable resource utilization.

Approximately 65% of regions analyzed show potential for improvement, emphasizing the urgency outlined in previous studies. Incorporating these insights into policymaking and stakeholder initiatives can propel Catalonia toward a more resilient and prosperous future, aligning with global sustainability goals.

Table 1.. Descriptive statistics of the input parameters used in the DEA model.

Variable	*Parameter types*	*Units*
Industrial water consumption	Input	m3
Domestic water consumption	Input	m3
Total water consumption	Input	m3
Gross domestic product (GDP)	Output	millions of euros

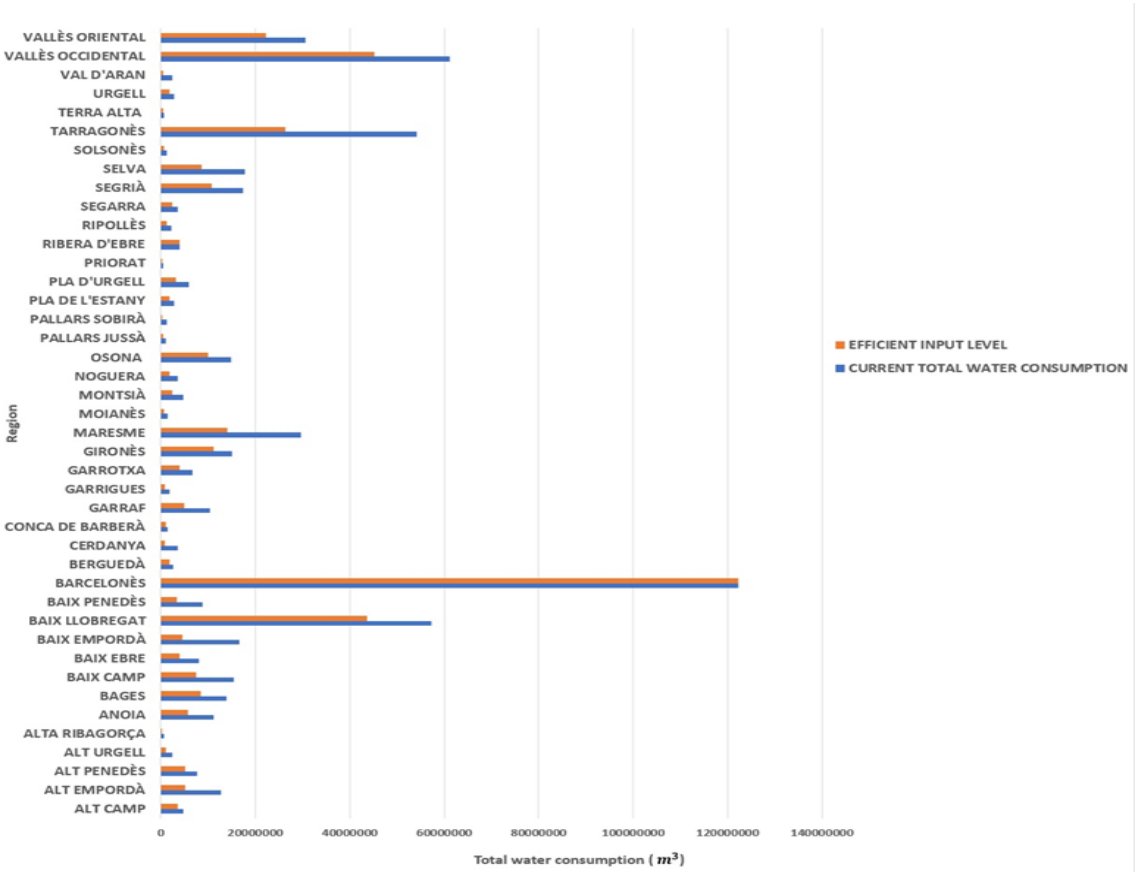

Figure 1. Comparative analysis of industrial and domestic water consumption: current input levels vs. efficient input levels with constant GDP output.

Acknowledgment:

Special thanks to Ms. Haniyeh Zavarogh for her support.

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Aggregates production from construction and demolition waste (CDW)

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Keywords: Aggregates, Concentration, Concrete, Contaminants, Jigging Process

The construction and demolition industries generate around 900 million tons of waste per year, in the European Union [1]. CDW is a mixture of different solids. However, part of the CDW consists of inert materials that can be reused in civil engineering as aggregates. Environmental concerns about CDW generation and accumulation rise yearly, reinforcing the need to reuse it as recycled aggregate for construction industries, because the sector has a great potential to absorb most of the CDW generation [2].

The potential for the recycling and reuse of CDW is high. Over the last decades, many studies have been performed to evaluate the feasibility of using CDW in many activities, such as concrete, mortar, ceramic materials, eco-friendly concrete blocks, geopolymers synthesis, geotechnical applications, use in sea-wall foundations, landfill cover layer, alternative pipe backfilling materials, asphalt, and roads [2].

The presence of contaminants limits the application of recycled aggregates (RA) in new concrete formulations. Analyzing the ways of reusing CDW, Brito, and Saikia [3] demonstrated that the presence of contaminants is the main factor that influences its possibilities of reinsertion into the production chain. The contaminants negatively influence the fundamental properties of the aggregates, such as size distribution, shape index, bulk density, and water absorption. The presence of contaminants directly affects the resistance and possible use of concrete manufactured using recycled material

According to Richardson [4], the most promising issue seems to be the use of coarse recycled aggregate in a new concrete formulation, which can reduce generated waste and can respond to increasing demand for aggregates. For that purpose, their separation by different constituents with similar properties is required. The CDW treatment plants in Europe present comminution and size separation, after light materials (paper and wood) and metals separation. In this way, the entire CDW is classified into different size ranges (5 x 20 mm), but the different constituents-concrete, brick (red ceramic), wall mortars, asphalt, natural stone, etc.— remain mixed [5].

A conventional jig is the most used equipment to concentrate CDW particles [5]. Jigging is a separation process, consisting of repeated expansion (dilatation) and contraction (compression) of a particle bed, using a medium, usually water or air. The result is the stratification of the bed

with increasing densities of the particles from the top to the base, generating different products. Figure 1 presents the flowchart of the comminution, sieving, and jigging processes to which CDW is subjected to concentrate the aggregates present in the material

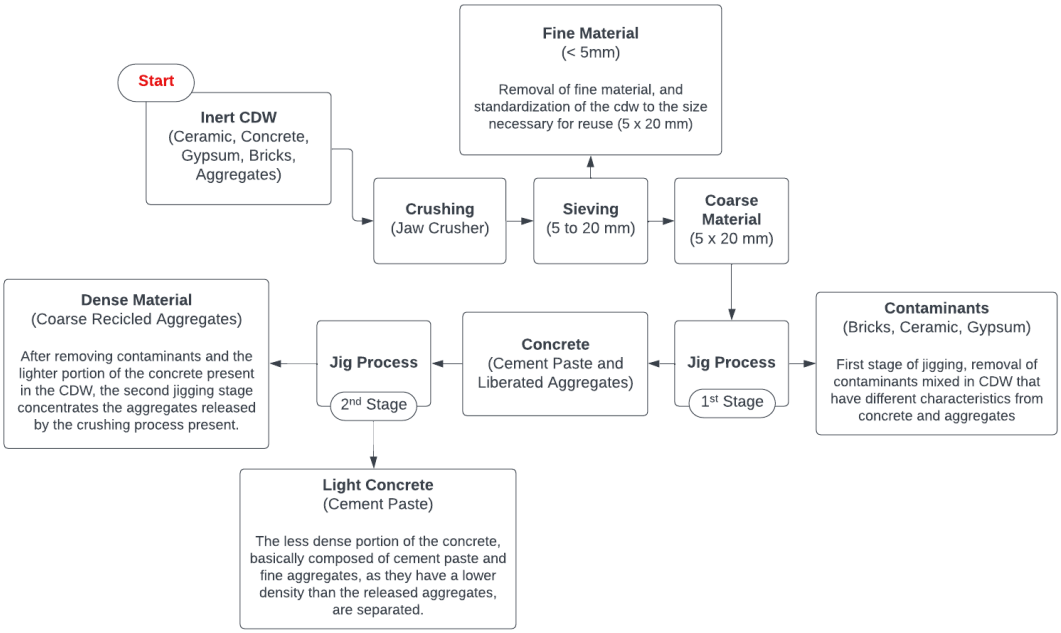

Figure 1. Flowchart of the comminution, sieving, and jigging processes of the CDW.

Main preliminary conclusions:

- Using the two-step jigging process, it is possible to eliminate the contaminants from the CDW and concentrate the aggregates present in concretes with characteristics very similar to those found in natural aggregates.
- Concrete has a very relevant density variation due to its composition (cement paste, coarse aggregates, and fine aggregates), the segregation of materials generates particles composed only of cement paste, middlings with cement paste, and coarse aggregates as well as the liberation of aggregates present in the material.
- It is possible to concentrate more than 80% of the material with a density >2.6g/cm3 with just one jigging stage
- It is possible to generate final products with low impurity contents, and a grade of higher than 99% of concrete. This concentrate presents enough purity to be used as recycled aggregate;

Acknowledgment:

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Research into organic friction modifiers with improved environmental compatibility to omptimize their tribological behavior over a wide range of temperatures

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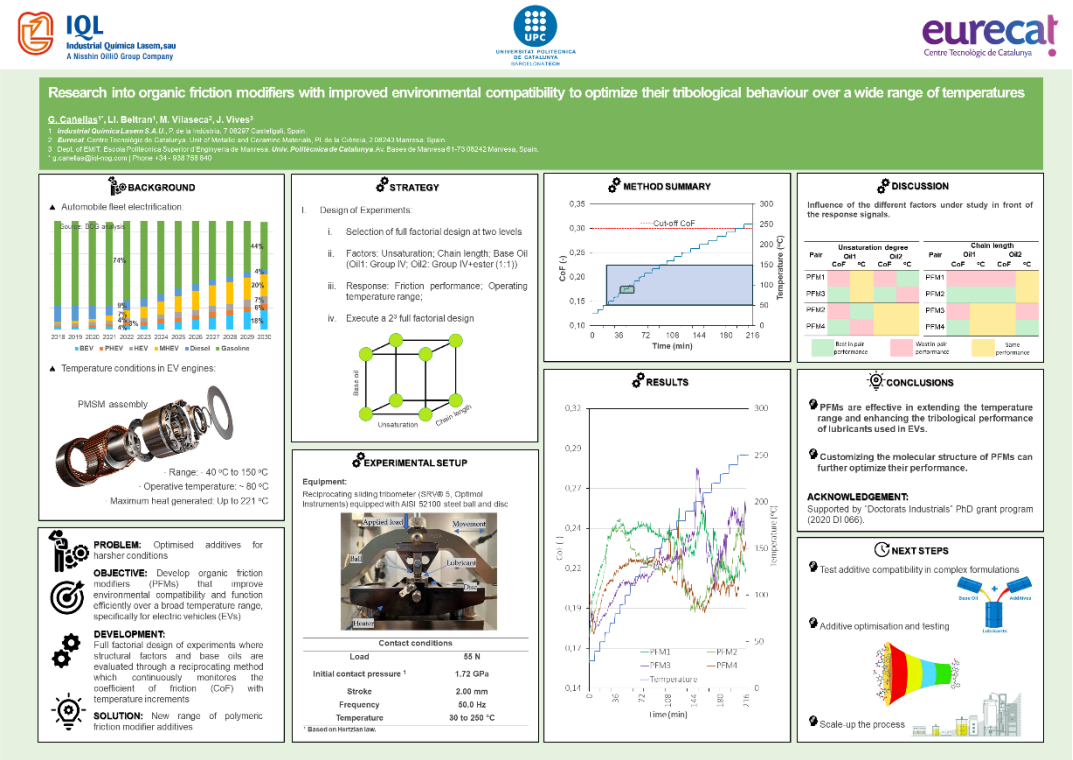
Keywords: Additive; Electric vehicle; Friction modifier; Tribological behaviour; Temperature behaviour.

Graphical Abstract



Electric vehicle (EV) engines can operate within a temperature range from approximately -40 °C up to 150 °C. The average operative temperature is around 80 °C, but the heat generated from the motor can reach up to 221 °C [1]. This wide operative temperature range creates the need to develop additives capable of efficiently working in this range.

In line with this objective and following the development of the thesis [2], a full factorial design of experiments is being executed. For this purpose, an in-house method has been developed using a reciprocating sliding tribometer (SRV® 5, Optimol Instruments, Figure 1), with point contact between an AISI 52100 steel ball and disc at set conditions (see Table 1). In this method, temperature is incrementally increased while coefficient of friction (CoF) is continuously monitored.

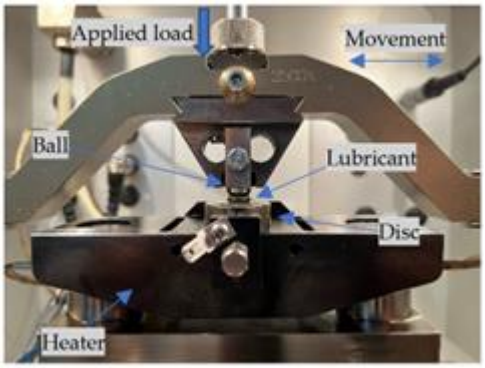


Figure 1. SRV assembly representation.

Table 1. Test parameters.

Contact conditions	
Load	55 N
Initial contact pressure	1.72 GPa
Stroke	2.00 mm
Frequency	50.0 Hz
Temperature	30 to 250 °C

Several laboratory prototypes of polymeric friction modifier (PFM) additives [3] have been evaluated with different structural factors (unsaturation and chain length) and different base oils (polyalphaolefine 4+6 (PAO) and polyalphaolefine 4+6 + ester (BO)), to understand the influence of each factor and design an optimum product (see Figure 2).

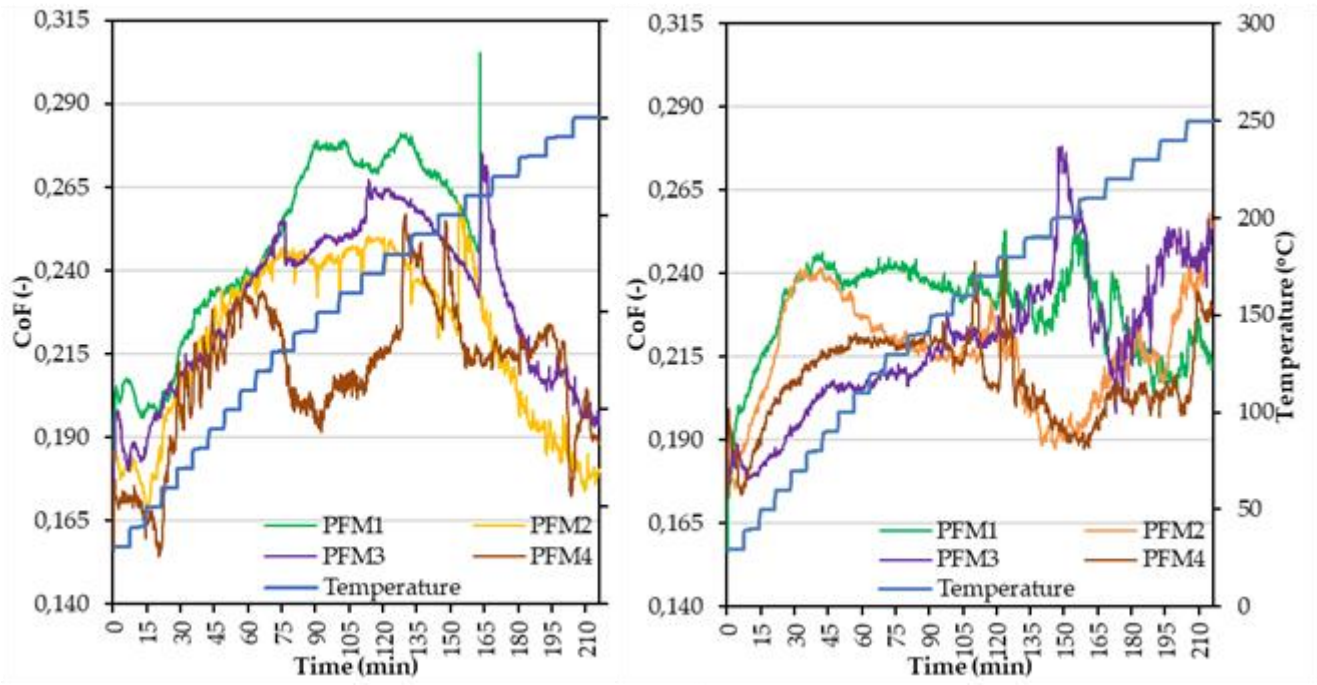


Figure 2. (a) CoF curves of the formulations containing the PFMs in PAO base oil; **(b)** CoF curves of the formulations containing the PFMs in BO base oil.

An improvement in the operational temperature range of the base oils has been observed when a PFM is added. The addition of PFM surpasses the working temperature range and, in most cases, reaches the maximum test temperature regardless of the base oil.

According to the conducted study, PFM additives emerged as preferable due to the thermal stability, providing better control over the CoF and surface protection at high temperatures. Lubricity can be optimized by controlling chain size and introducing a certain degree of unsaturation without compromising thermal stability.

Acknowledgment:

This work received the support of the Pla de Doctorats Industrials from Secretaria d'Universitats i Recerca del Departament d'Empresa i Coneixement of the Generalitat de Catalunya (2020 DI 066).

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Study of strategies for sulfidogenic process improvement through artificial biomass immobilization and monitorization of biomass using electrochemical H2S sensors

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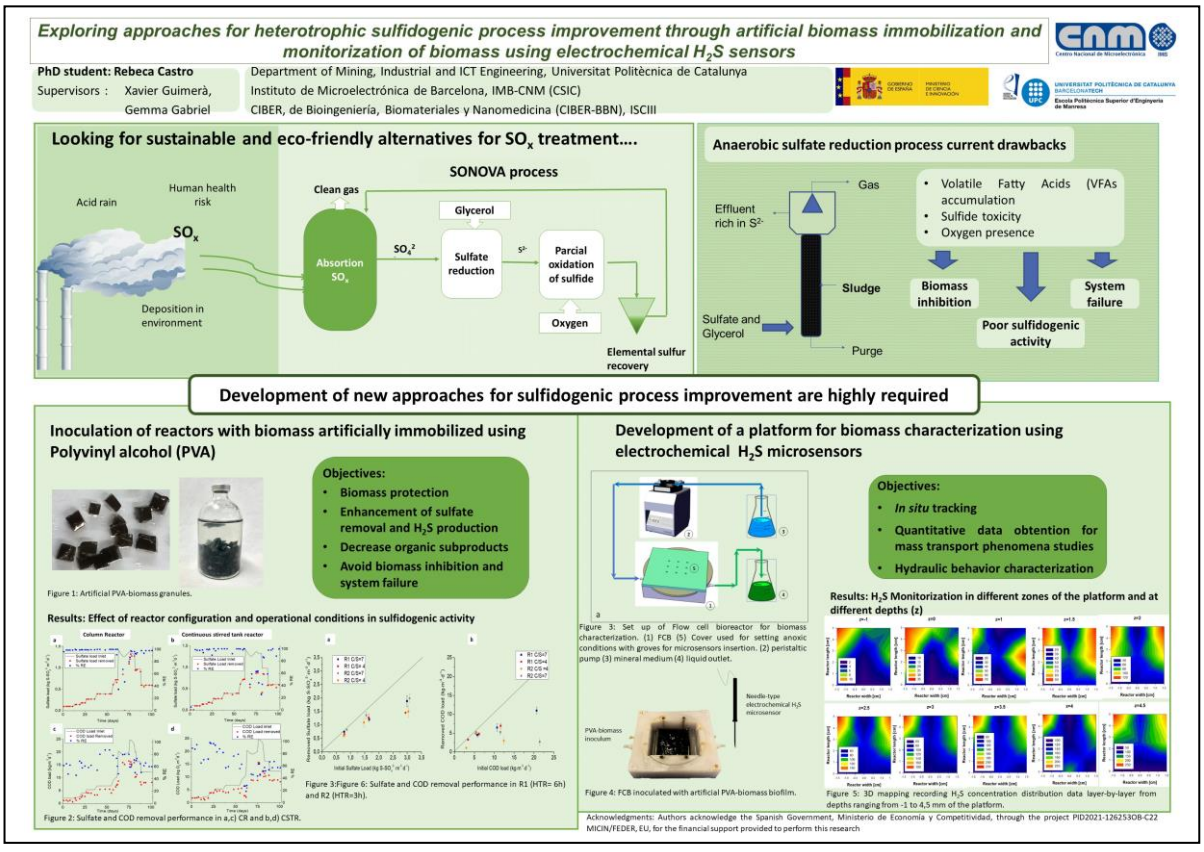
Keywords: Sulfidogenic sludge, Artificial immobilization, PVA, H_2S Microsensors

Graphical Abstract



Introduction

Air pollution, particularly caused by flue gases from combustion processes in industrial sectors, poses a serious risk to public health and the environment. Specifically, to address the problem of SO2 emissions, SONOVA process have been developed. This process consists of a first step where SOx is absorbed using a slightly alkaline solution, a biological step where absorbed SOx

(as a mixture of sulfate and sulfite) is anaerobically reduced to sulfide using glycerol as electron donor, and an aerobic sulfide oxidation step to obtain elemental sulfur. The sulfate-reduction process plays a crucial role in the biological valorization of SOx gases and is the process bottleneck due to several drawbacks are reported, mainly related to maintaining a long-term efficiency and avoiding process failure caused by the inhibition of the biomass by Volatile Fatty Acids (VFAs) accumulation, sulfide toxicity, and oxygen presence.

On one hand, immobilization of biomass using synthetic polymers has been positioned as a promising approach for biomass immobilization. Synthetic granules improve reactors performance due to the generation of a protecting matrix that allows a decrease in starting up period and a fast adaptation to new conditions. These methods can be an alternative for natural immobilization through Exopolysaccharides EPS production in cultures that have a slow production of these compounds. In addition, it has been described that polymer-biomass granules increase the mechanical strength of synthetic granules, preventing bacteria wash out.

On the other hand, a complete understanding of the sulfidogenic process in bioreactors is limited by the lack of technologies for characterizing the sulfate-reducing activity of immobilized biomass. In that sense, development of a system for sulfidogenic activity measurement using electrochemical H2S sensors is an interesting approach for biomass characterization due to allow measurements in situ, in different areas and depths of biofilms, with high accuracy and sensibility.

Therefore, this thesis proposal is to study different approaches to improve biological sulfate reduction operational suitability of using artificial granules as inoculum as well as, developing a tracking system for biomass characterization using electrochemical H2S sensors.

Methods

Since biomass natural immobilization of sulfidogenic sludge was not achieved due to poor EPS production, several studies were performed to select a polymer-biomass matrix that maintained sulfate-reducing activity of biomass while providing strong microbial retention and mechanical strength.

In order to study the effect of the inoculum of artificial PVA-biomass, two reactors configuration were studies: Colum Reactor (CR) and Continuous Stirred Tank Reactor (CSTR). Reactors were inoculated an operated for 90 days, evaluating sulfate removal, glycerol intake and organic subproducts accumulation. Besides, suitable configuration was used for study appropriate operational conditions in order to obtain maximum substrate load that achieves more than 90% of sulfate reduction and leading the lowest COD and VFAs concentration in the effluent.

Besides, the development of a system for characterization of biomass using H2S electrochemical sensors was assessed in a flow cell bioreactor, where several operational conditions were tested and H2S profiles were obtained. Additionally, a 3D-mapping was recorded in order to perform a hydraulic characterization.

Results

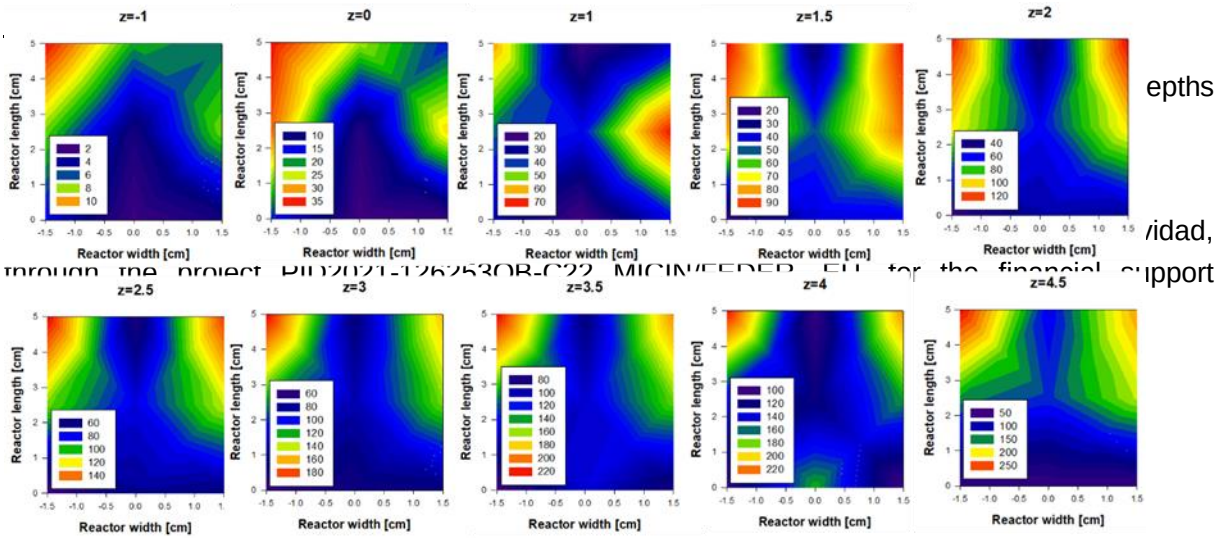
Artificial immobilization using PVA has been selected due to generated artificial granules with high mechanical strength and stability as well as remained sulfidogenic activity.

1. Operational conditions study

A 90-days operation of CSRT and CR reactors inoculated with artificial PVA-biomass granules de demonstrated a stable removal of sulfate and granule retention in CR. On the other hand, study of suitable operational conditions in CR presented more than a 90% of sulfate load removal and a low glycerol subproducts accumulation using C/S ratio of 4 (Kg O2/Kg SO42-) and an HTR of 6h.

2. Development of a platform for biomass characterization using H2S electrochemical sensors

Appropriateness of a flow cell bioreactor inoculated with artificially immobilized biomass was evaluated by H2S profiling at different sulfate loads. In all conditions, accumulations of H2S in the bottom of the FCB was presented, due to the rate of H2S production was higher than the rate of H2S diffusion in the PVA-biomass matrix Besides the 3D-mapping recorded in Figure 1 presented the differences in H2S accumulation between center and side locations of FCB showing a velocity profile generated in a laminar flow operation, which generated an axial dispersion of H2S.



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through the project PID2021-126253OB-C22 MICIN/FEDER, EU, for the financial support

Figure 1: 3D-mapping recording H2S concentration distribution data layer-by-layer from depths (z) ranging from -1 to 4,5 mm of the platform.

Acknowledgment

Authors acknowledge the Spanish Government, Ministerio de Economía y Competitividad, through the project PID2021-126253OB-C22 MICIN/FEDER, EU, for the financial support provided to perform this research

Processing and characterization of metallic glasses prepared by centrifugal atomization

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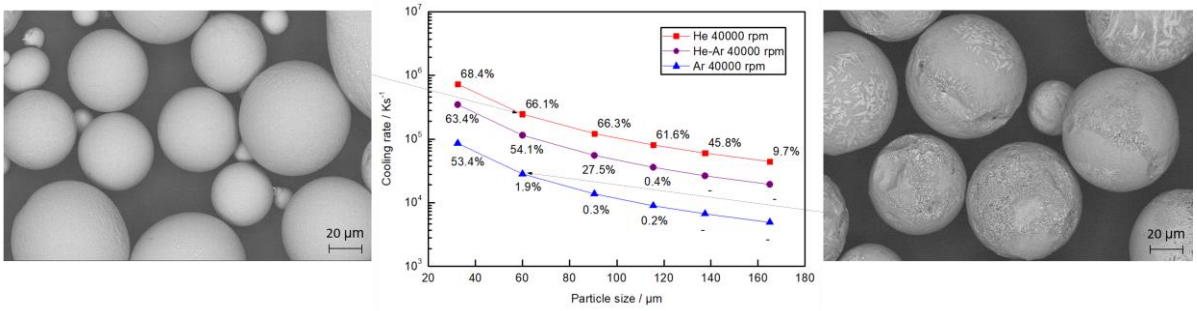
Keywords: amorphous fraction; centrifugal atomization; cooling rate; metallic glasses.

Graphical Abstract



The data points represent the amorphous fraction calculated from DSC for the corresponding mean particle size

The production of metallic glasses presents an opportunity for advancing materials science and engineering applications, offering a unique combination of mechanical characteristics that traditional materials struggle to achieve. Conventional materials often exhibit a trade-off between strength and toughness, but metallic glasses, with their non-crystalline structure, offer a promising solution to this challenge [1-3].

Despite their potential, widespread adoption of metallic glasses has been impeded by challenges in the production of these materials. Achieving the necessary cooling rates for amorphization is a demanding task, as they are limited by the time-dependent process of heat transfer, which in turn limit the dimensions of the final product. However, these limitations can be overcome through the production of powder and their subsequent consolidation. In this sense, centrifugal atomization emerges as a promising technique for the production of metallic glasses. By subjecting molten metal to high centrifugal forces, this technique enables the generation of fine spherical droplets with cooling rates in the order of 102 to 105 K/s, promoting the formation of the desired non-crystalline structure [4].

This doctoral thesis focuses on characterizing the centrifugal atomization equipment designed at the Fundació EURECAT, with the primary objective of enhancing the cooling rates of atomized particles for metallic glass powder production. To carry out this comprehensive study, a complete

theoretical and experimental research of the centrifugal atomization process is required. Theoretical efforts involve refining numerical models to understand the thermal behavior of atomized particles, significantly advancing our comprehension of cooling kinetics in this process of atomization. These models are validated through experimental methods to determine their applicability range, ensuring their utility in future investigations. On the experimental front, a systematic study is conducted on the effects of disk rotation speed, melt superheat temperature, and gas composition on the cooling rate of Al-Cu alloys and Al-based metallic glass forming alloys.

Furthermore, additional techniques are explored, such as introducing an external gas source into the conventional centrifugal atomization process to investigate the impact of gas flow on the cooling rate of atomized Cu powder.With the optimal adjustment of the atomization parameters, such as gas composition and disk speed, cooling rates of up to 10^5 K/s are achieved, with amorphous fractions of around 70% for particles smaller than 45 µm, and up to 50% in fractions of up to 125 µm in the Al-based metallic glass forming alloy of composition $Al_{86}Ni_8Y_{4,5}La_{1,5}$, as shown in Figure 1. The findings demonstrate that the centrifugal atomization process is well-suited for producing metallic glass powder tailored to meet the requirements of various industrial applications.

By conducting this study, this thesis lays the groundwork for the advancement of metallic glass powder production via centrifugal atomization. Future perspectives include further exploration in other alloy systems, such Fe-based glass forming alloys, making use of the acquired knowledge to continue improving production processes and expanding the application possibilities of these innovative materials across various industries.

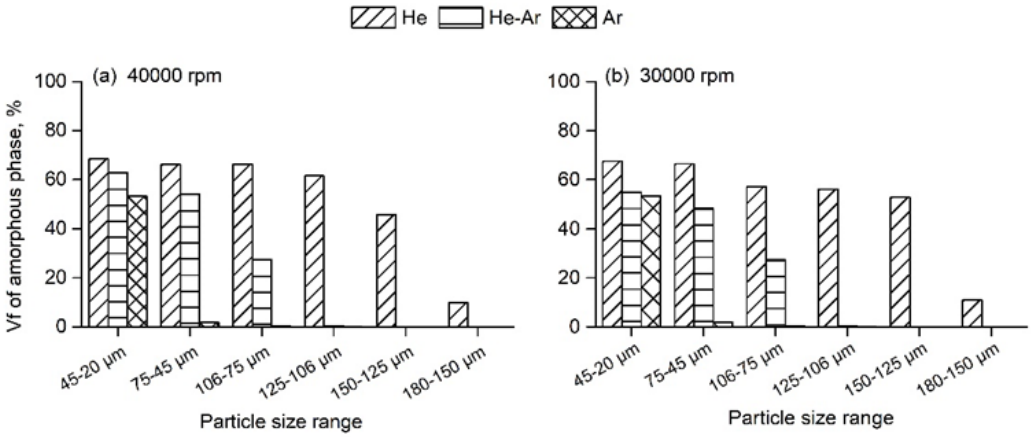


Fig. 1. Amorphous volume fraction of the centrifugally atomized $Al_{86}Ni_8Y_{4,5}La_{1,5}$ powder as a function of corresponding size range using different gas compositions: a) particles atomized at a constant disk speed of 40000 rpm; b) particles atomized at a constant disk speed of 30000 rpm.

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Flat-sheet MBfR Operational Framework Start-up for CO2 and H2 Biomethanation for PtM Strategies and Further Applications

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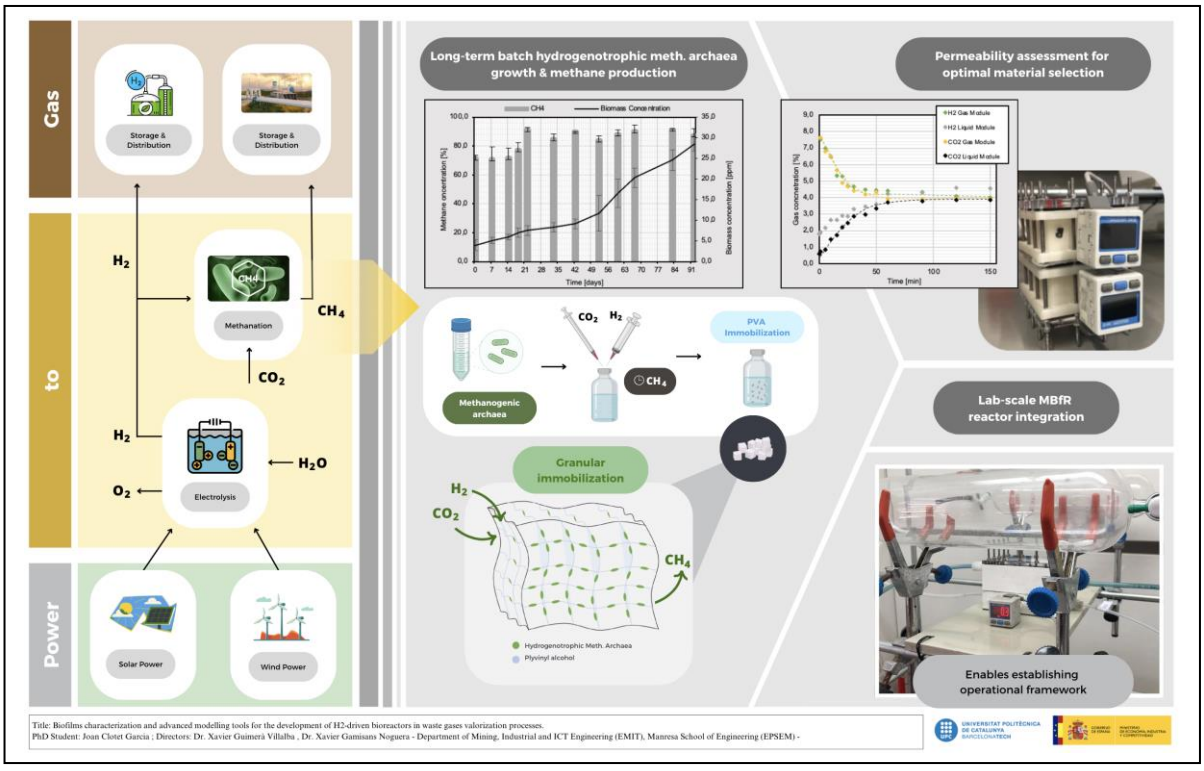
Keywords: Biomethanation, Power-to-Methane, Membrane Biofilm Reactor, Hydrogenotrophic Methanogenic Archaea, Polymeric Membrane

Graphical Abstract



Abstract

Power-to-Gas (PtG) strategies aim to identify the best gaseous energy storage pathways by employing energy vectors like H_2 and CH_4. PtG can be broken down into several branches, one being Power-to-Methane (PtM), which is presented as the alternative strategy that combines H_2 and CO_2 to achieve biomethanation (BM) so as to produce synthetic natural gas (SNG).

Although BM is a biochemical process carried out naturally by a group of methanogenic archaea, its replication on an industrial scale for the production of SNG faces significant limitations. It has been identified that the most severe is related to gas–liquid mass transfer issues, since both H_2 and CO_2 have very low solubility in aqueous solutions where BM takes place.

To this aim, different reactor configurations have been investigated with the focus on overcoming the bottleneck of gas–liquid mass transfer. In this sense, Lecker et al. (2017) stated that these limitations have been addressed by carrying out BM in membrane reactors, where the membrane acts as a mass transfer vector for H_2 and CO_2 between gas and liquid phases. At this stage it is crucial to characterize the properties of the membrane to ensure the selection of a material with the highest permeability and selectivity for H_2 and CO_2 capture and, eventually, BM reaction enhancement. Furthermore, Pratofiorito et al. (2021) demonstrated that direct feeding of substrate gases to the biofilm improved the mass transfer of H_2 in a custom-made hollow-fibre membrane biofilm reactor (MBfR) for hydrogenotrophic methanation (HM), with archaeal biofilms cultivated on membrane surfaces. Nevertheless, some of these limitations still remain unsolved, including the increasing of mass transport rates across membranes and the improvement of biological stage performance.

With the objective of boosting membrane technology for BM, a novel polymeric flat-sheet MBfR has been developed for studying BM at lab-scale in order to increase the knowledge of all mass transfer mechanisms and its influence on the biological steps. Additionally, this research involved the characterization of hydrogenotrophic methanogenic archaea activity, including inoculum selection, H_2 and CO_2 consumption and CH_4 production rates, both through natural biofilm growth and artificial immobilization of the archaea.

The novel flat-sheet MBfR, based on 3D printing technology, comprises a modular design, consisting of distinct modules tailored for gas and liquid phases. Both gas and liquid phase modules ensure sealing and adaptability for the integration of monitoring systems, facilitating real-time assessment of key parameters such as gas mixture concentrations and pressure gradient, which are imperative for mass transfer rate characterization. Between gas and liquid modules, a membrane is housed. In this configuration, the membrane serves as the interface of both phases, allowing the mass transfer of substrate gases from the gas module to the archaeal biofilms cultivated on the membrane surface of the liquid module.

Polyvinylidene fluoride (PVDF), polydimethylsiloxane (PDMS) and poly(vinyl alcohol) (PVA) membrane performances for capturing H2 and CO2 were evaluated, based on H_2 and CO_2 permeability assessment. Results obtained in dynamic permeability characterization tests (Figure 1a), presented in Table 1, revealed that the best material for capturing H_2 and CO_2 was PVDF. This material showed the highest permeability for both gases, and a close-to-unity selectivity, which describes PVDF as a material that does not exhibit a preference for one gas over the other, allowing high permeation values of both gases at a comparable rate.

Table 1. Permeability Characteristics of Polymeric Membranes for CO2 and H2 Gases

Polymeric Membrane Material	CO_2 Permeability (Barrer)	H_2 Permeability (Barrer)	CO_2/H_2 Selectivity
PVDF	8154	8363	0,98
PDMS	178	1237	0,14
PVA	39	37	1,06

As for the BM reaction, an assessment of the growth of hydrogenotrophic methanogenic archaea was carried out by monitoring it through protein analysis and methane production in a batch process over a long-term operation. Figure 1b depicts the growth of the culture in a simplified batch bioreactor, showcasing the increase in methane production rate and the biomass concentration.

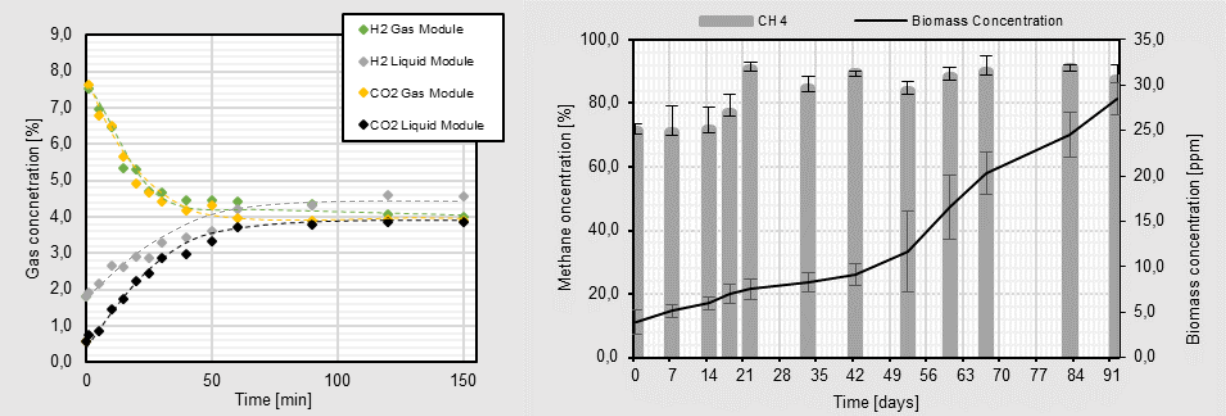


Figure 1. (a) Dynamic permeability characterization test. (b) Methane content in simplified batch bioreactor and biomass concentration.

Finally, BM process was integrated in the lab-scale flat-sheet MBfR. This operation allowed defining the combined substrate gases consumption up to 0.030 mmol h-1 as well as the methane production value up to 0.023 mmol h-1 when the culture was steadily operating under optimal conditions. These results demonstrated the feasibility of the selected culture for BM process.

Conclusions

This work establishes the operational framework for analysing BM within flat-sheet MBfR. Future studies performed through this reactor operation will lead to the identification of BM limitations, both due to mass transfer and biological activity, broadening the global understanding of BM process and optimising reactors operation.

Acknowledgements

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Contribution of transport sources to ambient air pollution levels in urban areas and in hotspots of traffic emissions

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Keywords: Air quality, Atmospheric particulate matter, Nanoparticles, Urban environment.

Introduction.

This thesis is carried out in the framework of two projects, Ri-Urbans (Research Infrastructures services reinforcing air quality monitoring capacities in European URBAN & industrial areaS) and AIR-PHONEMA (AIR Pollution in HOtspots: NEw Metrics and source Apportionment), which are being conducted at the IDAEA-CSIC (Institute of Environmental Assessment and Water Research) research centre, in the Geosciences department, with the EGAR (Environmental Geochemistry and Atmospheric Research) group in collaboration with other European and North American centres.

The main aim of the thesis is to assess the contribution of transport sources to ambient air pollution levels of atmospheric aerosols and gaseous precursors, using data from the last 10 years. These data have been measured continuously at three super-sites (road traffic, urban and regional background) and will be complemented by measurements at hotspots of transport in Barcelona (traffic, harbor, airport).

The hotspot sampling cabins are divided into 2 types:

- A fixed cabin in an urban traffic area that will sample continuously.
- A mobile cabin that will sample in concrete periods in the harbor and airport areas.

For the installation and sampling of these mobile sampling cabins, two campaigns will be realised, one in the Barcelona harbor area and the other in the Barcelona airport area.

Data adquisition

Measurement of concentrations of ultrafine particles (UFP, >1 nm) and atmospheric particulate matter (PM) samples will be done in the sampling cabins. After PM sampling, the chemical composition (elemental and organic carbon, ions, metals) and the oxidative potential (OP) of urban areas and hotspots will be determined in the laboratory. In addition, a quantification of the

sources contributing to PM and UFP will be made. This will be complemented by an evaluation of the OP of PM components and sources.

Work in progress

A filtering and correction of the PM, UFP and aerosol chemical composition data from 2014 to 2023 is currently underway, while samples obtained this year 2024 are still being sampled and analysed in the laboratory.

On the other hand, for this thesis it is intended to carry out 2 campaigns with a mobile cabin. The first campaign would take place in the harbor of Barcelona and the second at Barcelona airport. The design and preparation of this first campaign in the harbor of Barcelona is currently being devised.

Further work.

Carry sampling campaigns in the harbor and airport of Barcelona once they have been designed and placed in time.

Once each campaign has been completed, the samples obtained will be analysed in the laboratory and subsequently treated and corrected in order to extract the concentration, chemical and OP data for PM and UFP.

With the data obtained in the campaigns together with the data of the last 10 years, a process of interpretation of these results will be made, which will conclude in the elaboration of different scientific articles.

Finally, the published scientific articles and the data obtained during the thesis will be used to prepare the doctoral thesis report.

Exploring Critical Metal Recovery Potential in Greek Lateritic Ore: A Characterization Study

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Keywords: Characterization, Greece, Laterite, Metal Recovery, Raw materials

An industry's ability to operate sustainably depends heavily on raw materials, particularly metals. Advanced technologies including batteries, solar systems, optical fiber cables, electrical gadgets, catalysts, and synthetic fuels are all produced with their help. The healthy operation of the EU economy is largely dependent on the European manufacturing industry having sufficient access to certain mineral resources [1].

Greece, one of the mineral-rich nations in Europe, has a mining-friendly environment. The area has unique environmental issues and unique geological features that call for customized solutions. Owing to its extensive mining history, it presents substantial prospects for the extraction of metals [2]. Due to the large amounts of mining waste produced by this industry, mining waste must be managed properly to reduce any detrimental effects on the environment [2].

Greece has large lateritic ore reserves, and because these deposits may include important metals, there is increasing interest in using them. About the recovery of crucial metals—especially those necessary for the renewable energy transition and contemporary technology—this study will analyze these lateritic ores. This study assesses these deposits' potential for the effective recovery of metals like cobalt and nickel by thoroughly examining their mineralogical composition, element chemistry, and physical characteristics [3]. A comprehensive investigation was conducted using multiple analytical techniques such as chemical analysis, to determine the mineral composition, shape, and elemental distribution in the waste. The discovery of minerals rich in nickel, chromium, and other elements, as well as other economically valuable elements, was made possible by the results.

Greek laterite's complex mineralogical composition makes it possible to extract key metals selectively using a variety of extraction methods, including flotation and/or gravimetric procedures. Furthermore, the technology evaluation demonstrated complex mineral and elemental distributions driven by particle size fluctuations [4].

These revelations highlight the waste importance for processing and industrial use by providing important insight into its chemical variety. This all-encompassing strategy has the potential to promote sustainable resource management by fostering a diverse supply of vital metals, such as rare earth elements, which are crucial for a range of industrial applications.

Figure 1. Methods and sequence of characterization of laterite deposits in Greece.

Acknowledgment:

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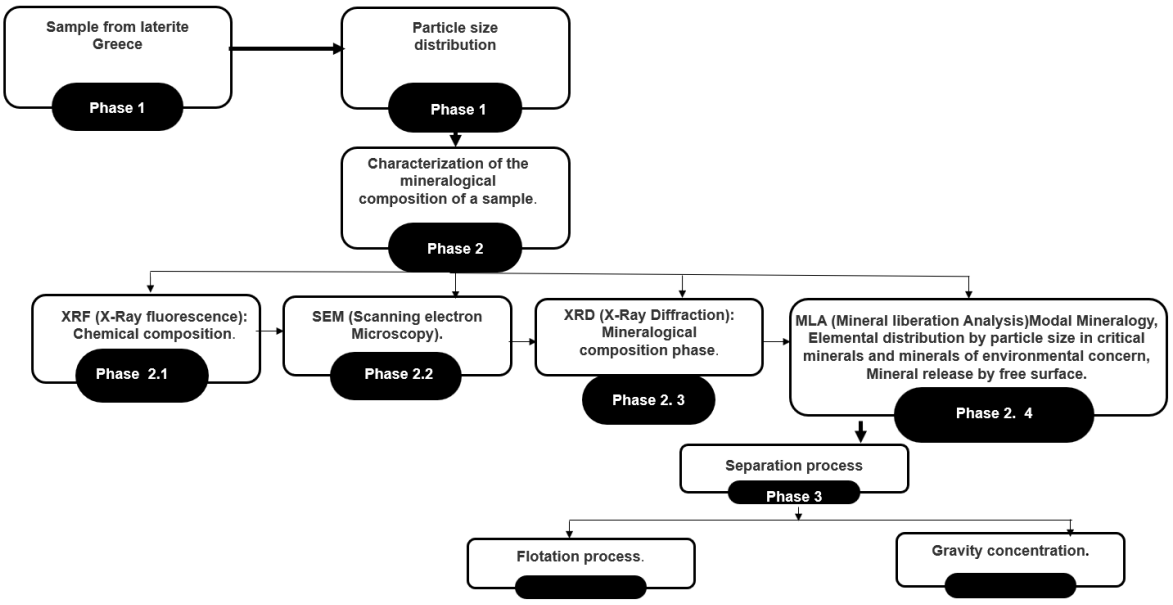

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Mineral liberation modeling of raw materials based on textural parameters from automated mineralogy

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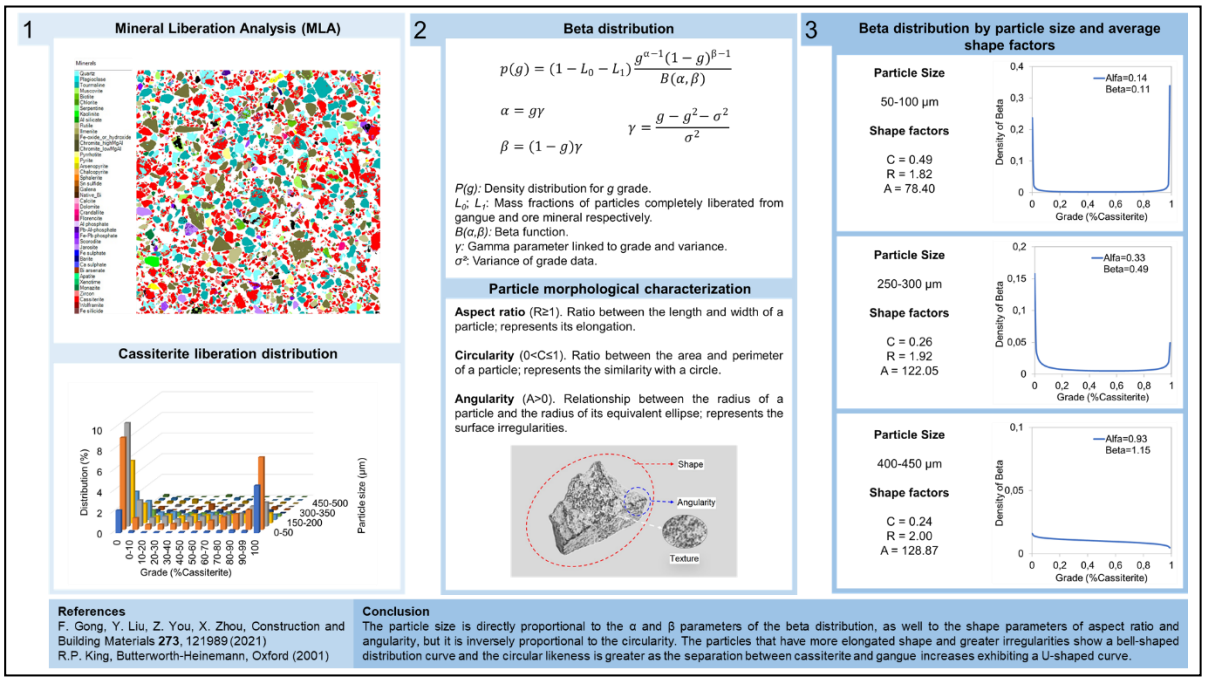
Keywords: Beta distribution, Mineral liberation, MLA, Modeling, Particle shape.

Graphical Abstract



This study investigates the phenomena of mineral liberation and its distribution using measurements from an automated analyzer, MLA (Mineral Liberation Analyzer). The primary objective is to correlate the parameters of a statistical function, the beta distribution, with various typical characteristics of minerals, such as particle size, grain size, mineral association and composition, among others. To achieve this, different minerals will be investigated, including the intrinsic relationships between the textural parameters of their particles, using various mathematical and statistical tools to generate a unified liberation model.

Liberation distribution

As an initial modeling attempt, the liberation distribution of cassiterite has been studied based on the results from the MLA (Figure 1). The grade is referred to as the percentage of the mineral in the particle, and since this is a 2D measurement, its value corresponds to the area presented (the sample studied has a cassiterite grade of 40.94%). In Figure 2 the distribution of cassiterite is in the range of 0 to 600 µm with intervals of 50 µm and its grade percentage is in different classes from 0% to 100%.

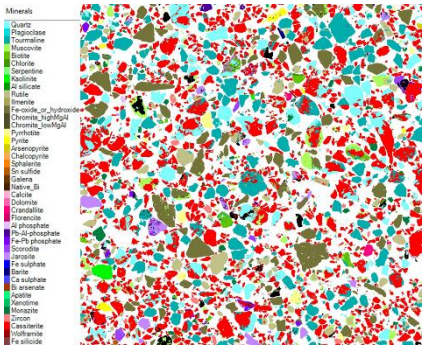


Figure 1. MLA image with the representative mineralogy of the sample.

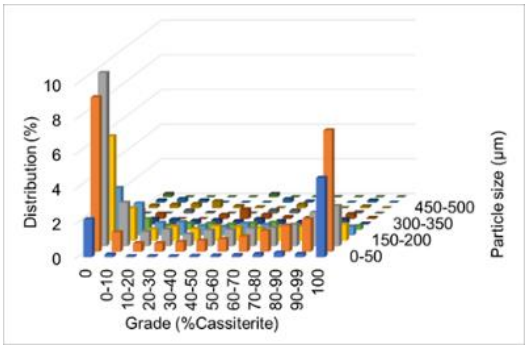


Figure 2. Mineral liberation distribution for cassiterite.

Cassiterite is liberated at sizes <200 µm, while the gangue is at <350 µm. As the size increases, the proportion of cassiterite becomes relatively constant across the grade ranges. Finally, for the coarser fractions, >350 µm, although the percentages are very low, there is a slight tendency for concentration in the intermediate ranges.

Beta distribution

The analysis of the cassiterite distribution has been conducted using the R.P. King [1] procedure, who defines the density distribution with the following beta function:

$$p(g) = (1 - L_0 - L_1)\frac{g^{\alpha-1}(1-g)^{\beta-1}}{B(\alpha,\beta)} \quad \text{Ec. (1)}$$

where g is the grade, L0 and L1 are the mass fractions of gangue and ore mineral, completely liberated, respectively, and B (α, β) is the beta function, wich is obtained using the following expressions:

$$\alpha = g\gamma \quad \text{Ec. (2)}$$

and

$$\beta = (1 - g)\gamma \quad \text{Ec. (3)}$$

where γ is given by

$$\gamma = \frac{g - g^2 - \sigma^2}{\sigma^2} \quad \text{Ec. (4)}$$

The mean grade and its dispersion (σ^2) are obtained from the MLA data, and from the results of the equations (2), (3) and (4) it is inferred that the variance is inversely proportional to particle

size and also to the values of α and β; conversely, the latter are directly proportional to particle size (Figure 3). This interpretation is consistently appreciable for particles <450 µm; for larger sizes, there are variations in the parameters that do not allow for continued correlation.

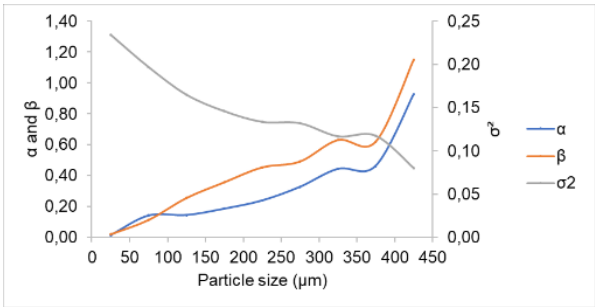


Figure 3. Relationship between particle size with parameters α and β and particle size with σ2.

The beta distribution tends to be a bell-shaped curve for coarse-grained sizes and takes on a U-shape for finer-grained sizes, as the particles tend to completely separate. The shape of the curve depends on the values of α and β: bell-shaped for higher values and U-shaped for lower values [2]. The density distribution of cassiterite (Figure 4) shows that the smallest particles exhibit an almost symmetrical U-shaped curve, which is achieved when α = β with a grade of ~0.5% [1] and shifts to the right because α > β [2]. As the size increases, the U-shape is maintained, but it subsequently shifts to the left due to the inversion of α < β [2]. The largest size fraction presents the beginning of the change towards a bell-shaped curve as α ≈ 1 and β > 1 [2].

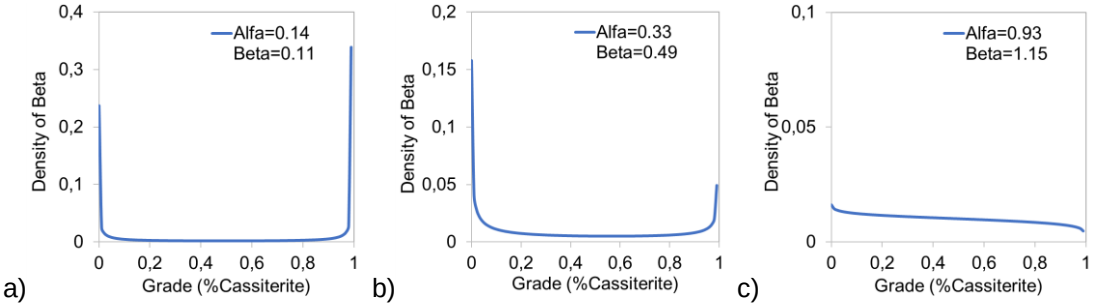


Figure 4. Beta density for the cassiterite liberation distribution. a) 50-100 µm, b) 250-300 µm, and c) 400-450 µm.

Particle morphological characterization

The characterization of the geometric irregularities of the particles can be represented by defining their shape, angularity, and surface texture [3] (Figure 5). The MLA provides three parameters related to particle form: (1) aspect ratio, related to particle elongation; (2) form factor, indicating the degree of circularity; and (3) angularity, referred to as the irregularity in the perimeter of the particles [4].

For the cassiterite, as the grain size increases, there is a tendency for the aspect ratio and angularity to increase, while circularity decreases (Table 1). Considering these results along with

the beta distribution, it is possible to infer that the morphological parameters are directly related to the α and β parameters. If α and β increase, the aspect ratio and angularity will also increase, indicating that the grains would have an elongated shape [5] and greater surface irregularities [4]. On the other hand, circularity values are inversely proportional to α and β and range between 0 and 1. The most circular shapes have values close to 1 [3] as the separation between cassiterite and gangue increases.

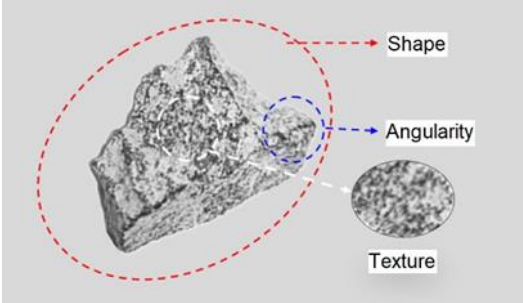


Figure 5. Morphological characterization of a particle. Modified from [3].

Table 1. Average morphological parameters for different cassiterite grain sizes.

	Morphological parameters		
Grain size (μm)	**Circularity**	**Aspect ratio**	**Angularity**
0-50	0.56	1.77	57.61
50-100	0.49	1.82	78.40
100-150	0.38	1.89	102.80
150-200	0.34	1.85	107.96
200-250	0.30	1.80	106.69
250-300	0.26	1.92	122.05
300-350	0.22	1.66	137.34
350-400	0.33	2.09	178.61
400-450	0.24	2.00	128.87
450-500	0.13	2.83	189.88
500-550	0.03	1.35	173.20

Acknowledgment:

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Forest precursor habitats (Catalunya, 1987-2022)

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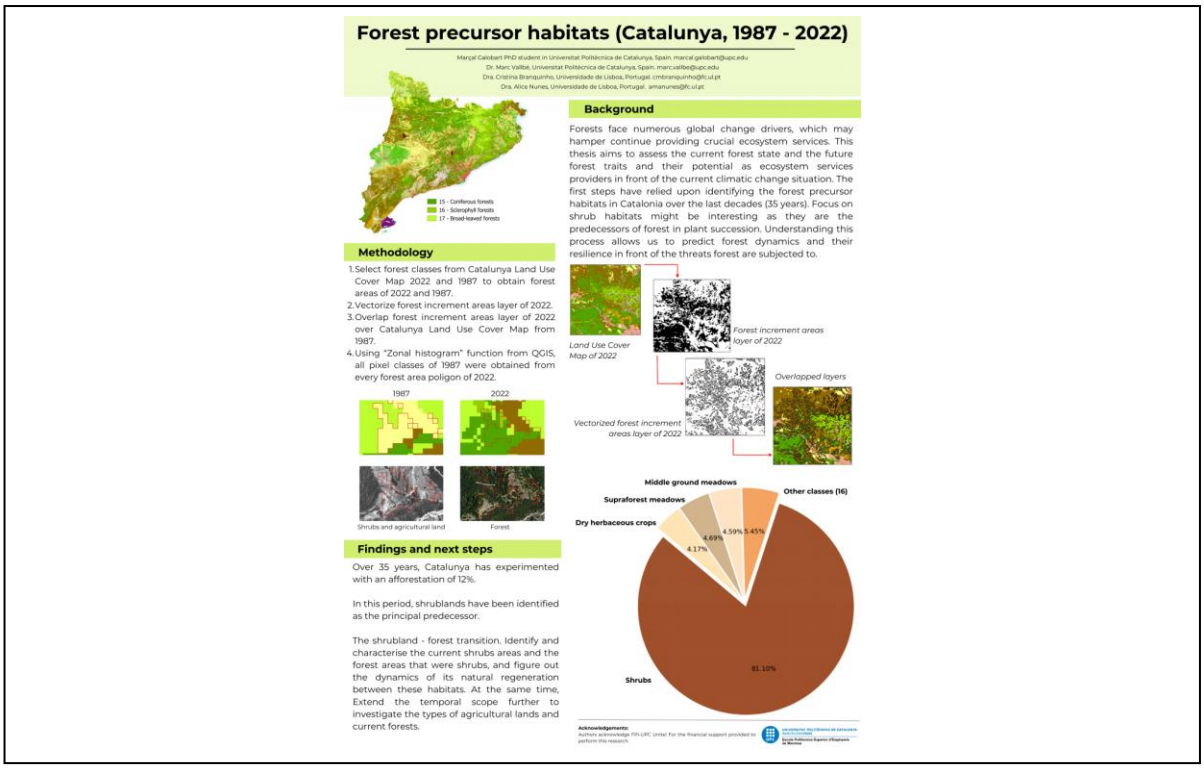
Keywords: Ecology, Forest transition, GIS, Land use, Natural regeneration

Graphical Abstract



Abstract

Forests face numerous global change drivers, which may hamper to continue of providing crucial ecosystem services (including climate change mitigation). Despite its urgent importance, the effects of the combinations of global change variables are not fully understood (Doblas-Miranda et al., 2016).

This thesis aims to assess the current forest state and the future forest traits and their potential as ecosystem services providers in front of the current climatic change situation. To study the future forest, the first steps have relied upon identifying the forest precursor habitats in Catalonia over the last decades (35 years). In this analysis, shrubs have been the principal predecessor of the

current forest. This will help in opening a research line on the natural regeneration dynamics of the current forest. Focus on shrub habitats might be interesting as they are the predecessors of forest in plant succession. Understanding this process allows us to predict forest dynamics and their resilience in front of the threats forest are subjected to.

Therefore, natural regeneration is a process that relies on interaction between biotic and abiotic factors. This is a slow and difficult-to-predict process due to the complexity of this interaction (Pardos, et al., 2005). Moreover, the current climatic changing situation could influence the resilience of future forest in front of perturbations and global change drivers (Buma and Wessman, 2013).

To carry out this analysis, Catalunya Land Use Cover Maps (MCSC, acronyms in Catalan) raster layers, elaborated by Centre d'Investigació Ecològica i Aplicacions Forestals (CREAF, 2010) were used. These maps have been made from 1987 to 2022, every five years. The MCSC raster layers are classified into 24 land use classes. Every class is represented in a pixel size of 30 x 30 m. Of the total classification, forest type is categorized into three classes: 15 - Coniferous forests, 16 - Sclerophyll forests and 17 - Broad-leaved forests.

First, the 1987 and 2022 MCSC raster layers were used to identify the forest area, for both years. The forest classes were distinguished from the rest, and then summed, to get all the forest area in Catalunya in 1987 and 2022 (Fig. 1. A). In this manner, the forest areas increment from 1987 to 2022 could be assessed.

After, the 2022 forest areas increment layer - only the ones that change to one type of habitat to forest - was vectorized to obtain the polygons of those areas (Fig. 1. A). Next, the vectorized layer was overlapped to the 1987 MCSC raster layer (Fig. 1. A). In this manner, it was possible to obtain every pixel class (every habitat type of 1987) inside every forest polygon of 2022 (Fig. 1. B).

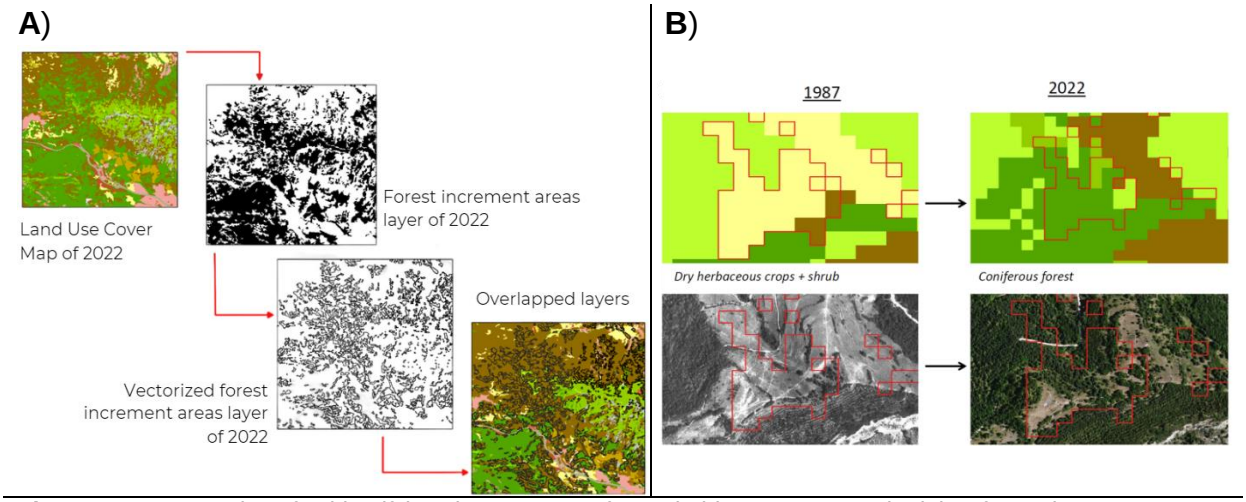


Figure 1. A. Procedure for identifying the precursor forest habitats. *Step 1.* Obtaining forest increment areas layer. *Step 2.* Vectorized forest increment areas layer. *Step 3.* Vectorized forest areas layer overlapped on 1987 MCSC. **B.** Visual inspection of the forest transition from 1987-2022. Above: there is represented the habitat change in 1987 and 2022 MCSC raster layers. Below: there is represented the habitat change in real orthophotos from 1987 and 2022.

To identify the habitat type of 1987 the function “Zonal histogram” of QGIS was used. This algorithm adds fields that reflect counts of each unique value from a raster layer. The output layer attribute table will present as many fields as the unique values of the raster layer that crosses the polygon(s).

The entire procedure was performed by QGIS (QGIS, 2024).

From 1987 to 2022 Catalunya experimented with an afforestation. In 35 years, forest areas have increased by 12% (Fig. 2). With the analysis explained before, the principal forest precursor habitat over the last 35 years is the shrub land (Fig 3).

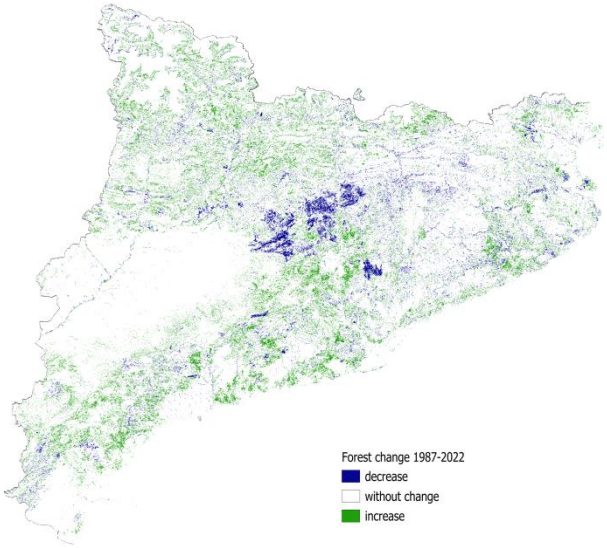


Figure 2. Forestland change in Catalunya over the last 35 years.

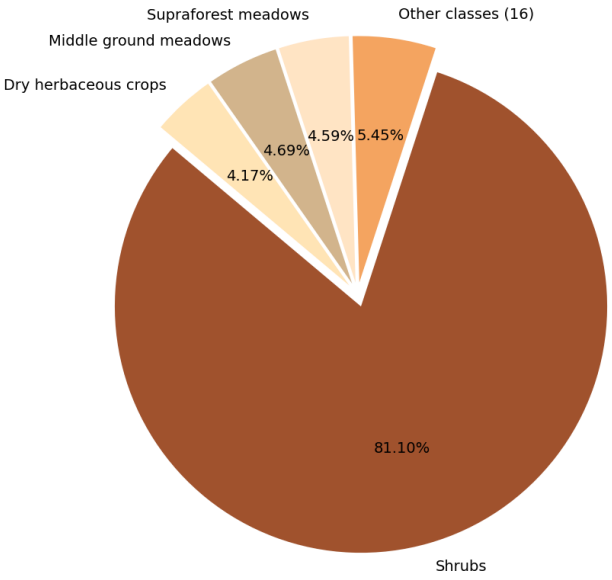


Figure 3. Principal forest precursor habitats from 1987 to 2022.

The reason of this low afforestation could be that it had happened before the 80s decade, coinciding with the rural exodus that Catalunya experimented over the last century (Vidal-Benito, T. 1979). This process brought a huge agricultural land abandonment that gradually have been changing to the next steps of plant succession (Cervera et al., 2019). Therefore, these shrublands may be the intermediate stages of the last agricultural land abandoned.

Next Steps

This analysis could be a prequel for future investigations lines. The research could continuous on different scopes:

- The shrubland - forest transition. Identify and characterise the current shrubs areas and the forest areas that were shrubs, and figure the dynamics of its natural regeneration between this habitats - study of the shrubs areas to predict their evolution to forest and resilience to global change drivers and extremes in semiarid regions.

- Extend the temporal scope further to investigate the types of agricultural lands and current forests. Examine forest restoration after agricultural abandonment, considering the influence of previous land use type and intensity, climate, and topography on current forests.

Acknowledgements

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Efficient Bio-Extraction Processes of Valuable Metals from Lithium-Ion Battery Scraps: Characterization, Mechanism, Pretreatment, and Optimization

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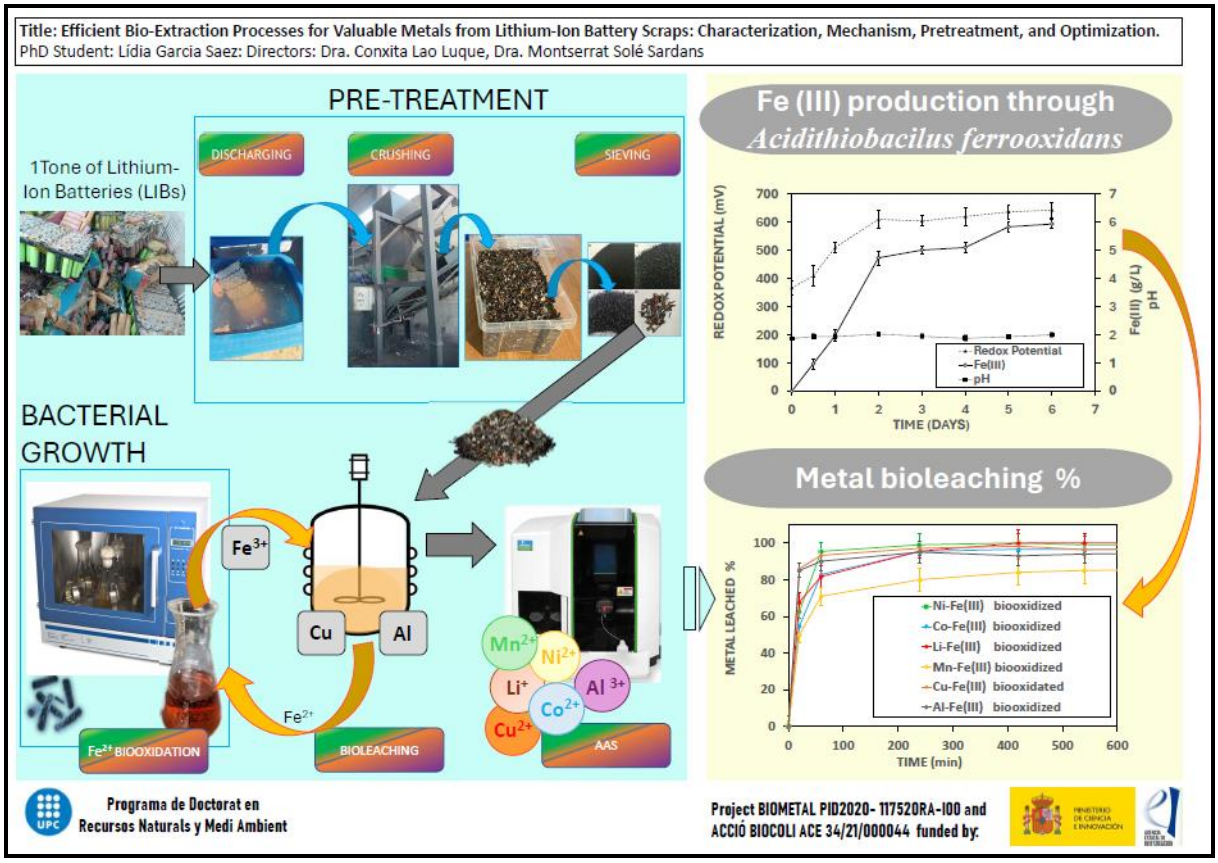
Keywords: lithium-ion batteries, biohydrometallurgy, e-waste, bioleaching, circular economy



Abstract

The growing consumption of electronic devices such as mobile phones, tablets, and computers has led to an increase in the use of rechargeable batteries. These batteries not only power electronic components but also play a crucial role in automotive transportation, electric mobility, and energy storage from renewable sources. This increase in demand has consequently raised the need for metals such as Co, Li, Mn, Ni, Zn, which are limited and non-renewable resources. Therefore, it is essential to design processes that can sustainably and environmentally friendly

recover these valuable metals from batteries, allowing for their reuse and contributing to resources conservation.

The primary objective of this thesis is to design a sustainable process for extracting valuable metals from lithium-ion batteries. To achieve this, three specific main topics have been addressed:

Preparation of Waste for Leaching: Waste battery streams are typically subjected to mechanical or chemical pre-treatment to facilitate subsequent processing and enhance the efficiency of metal extraction. Primary pre-treatment processes include dismantling, crushing, screening, heat treatment, mechanochemical techniques and dissolving. This pre-treatment plays a crucial role in separating and recovering active cathode materials and organic binders from the current collector, reducing the energy and time required for subsequent processes (Ghassa et al., 2020; Li et al., 2023; Moazzam et al., 2021). This study proposes a waste preparation process based on physical stages that minimize the energy input of the pre-treatment and prepare the waste in a way that maximizes the efficiency of subsequent extraction operations

Study of Metal Leaching and Extraction Using Acidophilic Microorganisms: Bioleaching technology for extracting metals from LIBs is based on the use of metabolites generated by the activity of acidophilic microorganism to dissolve the metals present in the electrodes. These metals exist in two different forms: elemental metals, such as Cu and Al in the current collectors, and oxides such as Li, Ni, Co, Zn, and Mn as active materials (Biswal et al., 2024; Esmaeili et al., 2020; Huang et al., 2019; Peters et al., 2020). The bioleaching of LIBs presents significant engineering challenges due to the slow kinetics involved. This impacts processing costs and cycle times and imposes limitations on their practical application for large-scale or industrial operations. In this thesis, studies focus on bioleach valuable metals using *Acidithiobacillus ferrooxidans and Acidithiobacillus Thiooxidans*. Various experiments were designed to understand the role of these microorganisms in the extraction process, the H_2SO_4 they generate, and the Fe (II) and Fe(III) ions in the solubilization process of metals from batteries.

Defining and Optimizing Key Parameters of the Leaching and Bioleaching Process: There are key parameters in the leaching process that can affect the efficiency of metal extraction, minimize energy input, and make the process more environmentally friendly. The parameters studied include pH, pulp density, type of leaching agent, and concentration of the leaching agent. A Design of Experiments (DOE) was carried out to optimize these parameters and consider the interactions between them.

Some key results of this thesis are presented below:

a.- Production of Fe (III) using *Acidithiobacillus ferrooxidans* Culture:

Fe (III) is the metabolite produced by *Acidithiobacillus ferrooxidans*, responsible for metal oxidation. A bacterial strain, *Acidithiobacillus ferrooxidans* (ATCC23270), kindly provided by the Department of Chemical Engineering at the University of the Basque Country (Spain) was used to obtain Fe(III). *A. ferrooxidans* was grown in 0K medium ($(NH_4)_2SO_4$ (3 g/L), $MgSO_4 \cdot 7H_2O$ (0.50 g/L), K_2HPO_4 (0.5 g/L), KCl (0.1 g/L), Ca $(NO_3)_2$*$4H_2O$ (0.014 g/L)) supplemented with $FeSO_4 \cdot 7H_2O$ (30 g/L). The pH of the medium was adjusted to 2.0 with 10% (w/w) H_2SO_4. 90 mL

of medium were inoculated with 10% (v/v) of inoculum from a pure bacterial preculture. Bacterial growth was carried out in 250 mL Erlenmeyer flasks in an orbital incubator at 30ºC and 110 rpm.

A. ferrooxidans growth was monitored over time by measuring the redox potential (Eh), pH, as well as Fe (II) and Fe (III) concentrations. The pH was maintained constant by periodically adding 10% (w/w) H_2SO_4 as needed. After 2 or 3 days of incubation, the culture took on a reddish color, indicating the formation of Fe (III). As shown in Figure 1a, after 6 days, all Fe (II) was oxidized to Fe (III).

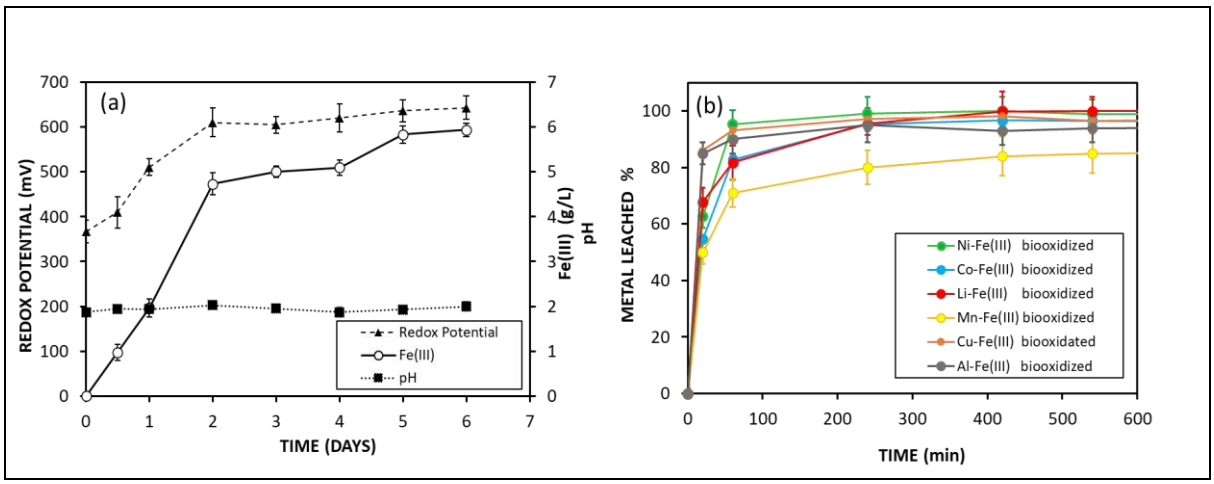


Figure 1. (a) Fe(III) production by *Acidithiobacillus ferrooxidans.* (b) % of metal extraction using Fe (III) biooxidized as leaching agent.

b.- Bioleaching results:

The best results for the bioleaching of metals contained in the Black Mass from scooter and bicycle batteries are presented in Figure 1b. The leaching agent was produced by the biooxidation of Fe(II) through *Acidithiobacillus ferrooxidans*. The results show that Cu and Ni were extracted at rates over 90% within just 20 minutes, and Al, Co, Mn, and Li were extracted at rates over 85% within 30 minutes. These results were achieved by optimizing the extraction process, operating at pH 1.5, with a pulp density of 1%, and a leaching agent concentration of 6000 ppm Fe(III).

Conclusions:

This study proposes an environmentally friendly and sustainable metal leaching process.

The sample preparation method involves a discharge process followed by crushing to a size smaller than 500 microns, without requiring any thermal or chemical treatment to remove the binder present in the residue. This approach minimizes crushing time and reduces energy consumption by avoiding thermal processes and the use of strong chemicals to remove the binder.

Broadly, it suggests the use of bioprocesses, where biooxidation of Fe(II) to Fe(III) by *Acidithiobacillus ferrooxidans* produces a leaching agent capable of extracting valuable metals from lithium-ion batteries.

By optimizing biolixiviation process variables, the study proposes operating at pH=1.5, with a pulp concentration of 1.5% and a leaching agent concentration of 6000 ppm Fe(III). Under these conditions, the biolixiviation process achieves extraction of Cu and Ni (over 90%) within just 20 minutes, and Al, Co, Mn, and Li (over 85%) within 30 minutes.

Acknowledgements:

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Water – Energy Nexus: A sustainable binominal

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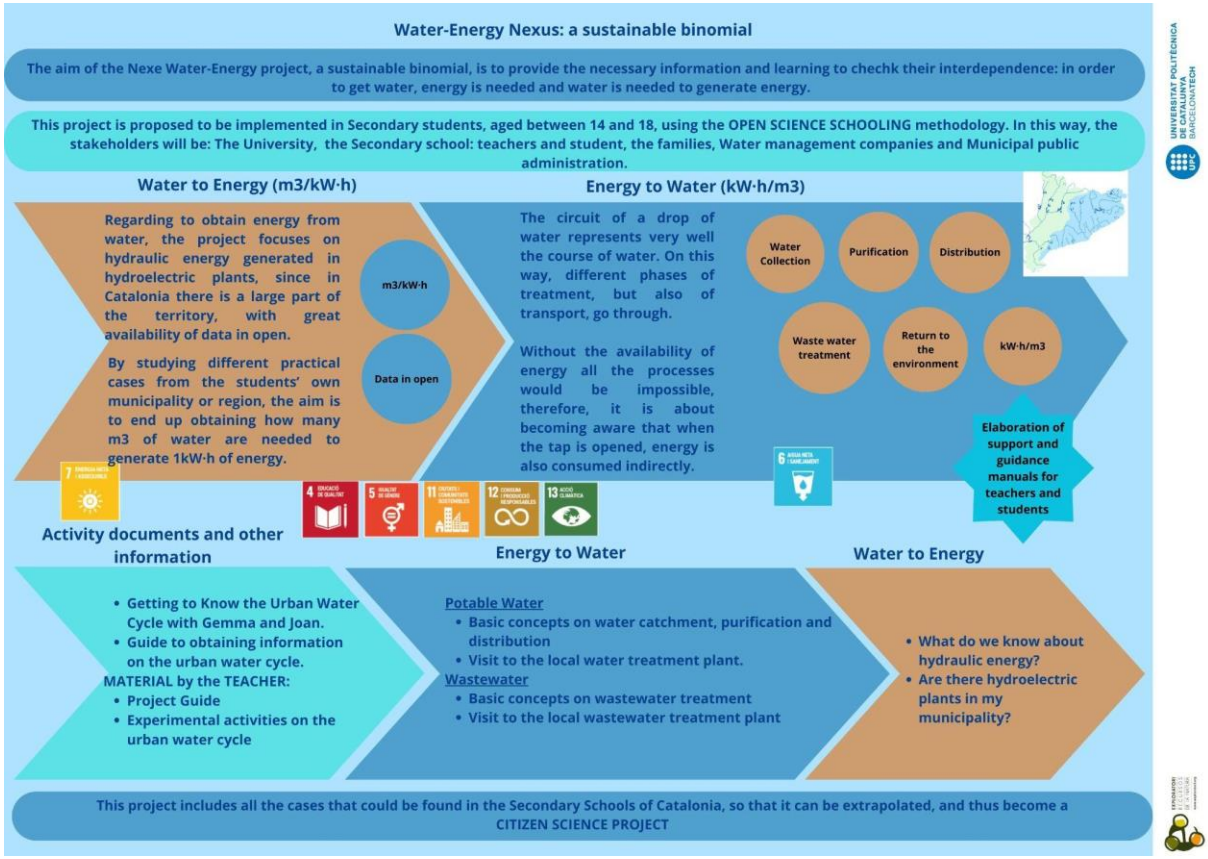
Keywords: Water, Energy, Open Science Schooling, Citizen Science, Secondary School.

Graphical Abstract



Two services that are essential to the well-being of people today are access to water and electricity. It must be taken into account that, in many cases, one depends on the other. As a result, there are two possible relationships:

The water needed to obtain energy.

The energy needed to obtain water.

Firstly, we analyze the energy needed to obtain water: both the treatment of drinking water and the treatment of wastewater and its discharge and return to the environment.

When treating fresh water to obtain drinking water, it is frequent to use gravity to transport the water. Nevertheless, in many cases pumping systems are needed to access elevated parts of

cities and, on occasion, to transfer river water to treatment plants (WTP). Some impulse is also needed within the plant itself, especially if closed filters are used. When groundwater is used, the need for pumps is evident.

Wastewater is transferred to wastewater treatment plants (WWTP) using gravity. However, once there, different treatment processes need energy for correct operation. Although it is possible to try to prioritize the movement of water using gravity, part of the process will require mechanical and/or electromechanical equipment that consumes energy.

In this project, secondary schools are provided with materials including indications of the steps to follow. These take into account the two water treatment approaches and their energy requirements:

Water enters the city to serve as drinking water.

Water leaves cities and returns to rivers and streams.

Once schools have been finished with their tasks, the resulting data is collected using Google Forms; this data allows us to see each city's circumstances and assess the water-energy nexus. As a result, we end up with the kWh needed for the treatment of each m3 of water (both drinking water and wastewater).

Finally, the project studies the relationship between the water needed to produce energy. In this case we work only with hydroelectric energy, therefore energy obtained with water.

Hydroelectric energy is very common throughout the Catalan territory, for this reason, it can be extrapolated to any secondary school in Catalonia. And it will be possible to work on the search for data from centers close to the secondary schools. The final goal is to end up with the m^3 needed to obtain 1 kwh.

This project is intended for secondary and high school students aged 14-18, and uses the **OPEN SCIENCE SCHOOLING** method. As a result, the stakeholders are:

- The University
- The secondary school: teachers and students
- Families
- Water management companies
- Municipal administrations

In some towns, the necessary data is available on the website of the city council or water management company; if this is not the case, participants must contact the council member responsible for the environment and/or water management. It should be noted that, in some cases, different individuals are responsible for drinking water and wastewater treatment.

As explained, this project includes all the cases that can be found in the Catalan territory, therefore it will be applicable from any secondary school in Catalonia, in this way it can be extrapolated and thus become a CITIZEN SCIENCE PROJECT

Acknowledgment:

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Experimental approaches to reduce PM emission modelling uncertainty

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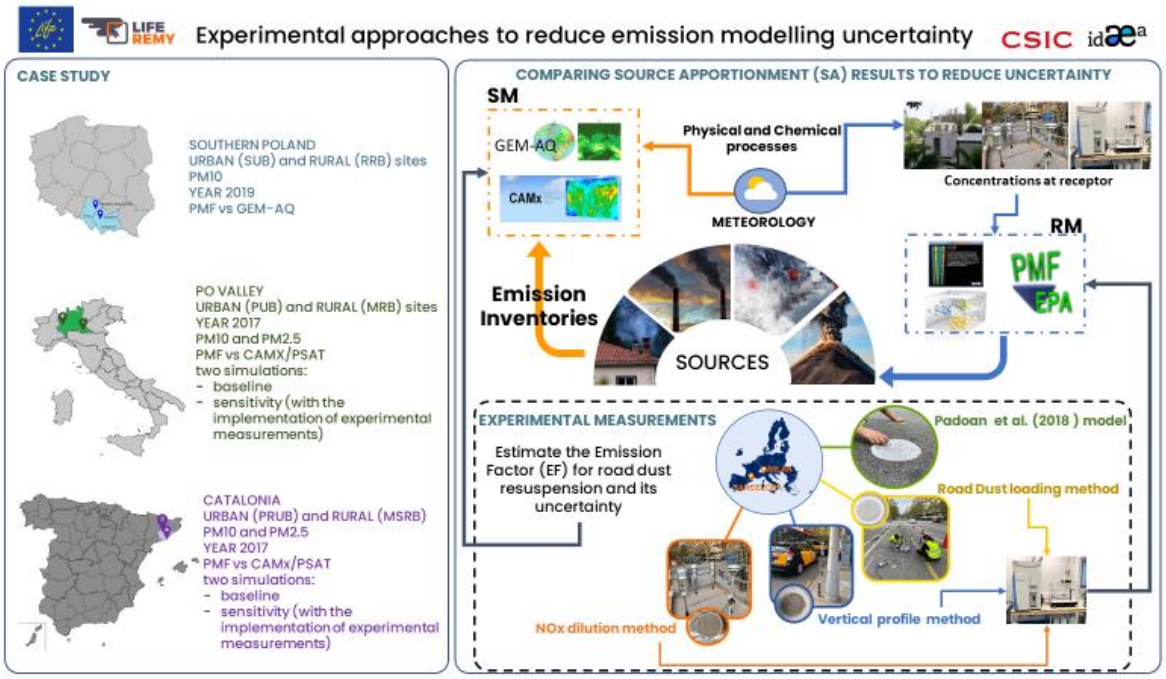
Keywords: PM, Receptor model (RM), Source oriented model (SM), Source Apportionment (SA), Road dust resuspension, Residential and Commercial Heating

Graphical Abstract



Air pollution is responsible for 6.7 million annual premature deaths globally [1], being the 4th major risk factor and the first of environmental origin. Urban concentrations of particulate matter (PM) across the European Union (EU) have not decreased over the last decade [2]. Therefore, it is necessary to improve air quality plans and mitigation strategies further. Source Apportionment (SA) is the most common modelling practice to address air quality plans and mitigation strategies. SA quantifies the Source Contribution Estimates (SCE) at a given receptor or over a geographical domain and it can be performed either by receptor models (RMs), or source-oriented models (SMs) [3]. The integration of RMs and SMs SA analyses can help identify uncertainties in source contributions and modelling processes, which could represent the best practice to reduce those

uncertainties. However, according to the European Commission review [4], only a few studies have combined RMs and SMs.

Hence, due to the limited information available in the literature and the lack of a standard methodology to compare the SA results obtained by different techniques.

The first objective of this study is an intercomparison exercise which aims to develop a methodology to compare the RM and SM information to evaluate the correctness of SA analysis by using SMs and identify uncertainty and gaps between RMs and SMs and how to reduce them. This intercomparison exercise combines the outputs in Po Valley, Catalonia and Southern Poland regions, at urban and rural sites. In the RMs approach, the Positive Matrix Factorization [5], [6] (PMF- (EPA-PMF 5.0 software)) technique on PM10 and PM2.5 (only for Catalonia and Po Valley) chemical speciation data were collected over several years including elements, ions, and OC/EC. In the SMs approach, The CAMx/PSAT [7], [8] model was used for the Po Valley and Catalonia regions in 2017 and the GEM-AQ model [9] for the Southern Poland region in 2019. The main results allow us to evaluate the information on emissions contained in the different Emission Inventories (EI) used in terms of emission characterisation, data activity of the emission and temporal modulation, and also the uncertainty produced by using a Regional emission inventory instead of a local one.

The second objective of this study is to estimate the Emission Factor (EF) of Road Dust Resuspension (RDR) since the majority of the EI is not included. RDR emission is an important source of ambient air PM in European cities, as evidenced by numerous SA studies using experimental observations and RMs SA. However, the capabilities of regional and local SMs to simulate RDR are severely hampered by the scarce knowledge of EFs and their spatiotemporal variability. Moreover, a standardized approach for calculating EFs does not exist yet, therefore an additional uncertainty is due to the choice of one among the methodologies available in the literature. RDR emissions uncertainties were estimated using three main methodologies:

To estimate the uncertainty related to the base EF an inter-comparison approach was followed using (and partially improving) four experimental methods simultaneously. The four methods are: i) the NOx dilution method [10] ii) the vertical profile method [11]; iii) the Padoan et al. (2018) model [12], based on road features and iv) the road dust loading method [13]. This comparison was performed in Barcelona, while methods II and III were compared in Milan.

To estimate the uncertainty due to the spatial variability of EF, the approach proposed by Padoan et al. (2018) was applied at 10 sites in both Milan and Barcelona.

The uncertainty linked to temporal variability is estimated based on previous work [14].

The combination of the first and the second objectives represents a third approach to address the emissions uncertainty reduction. The SA results from the CAMx/PSAT model were updated and implemented with the EFs of RDR estimated at objective 2. The results were compared with the PMF results for the Po Valley and the Catalonia domains.

This study highlights some crucial points:

Objective 1:

The main outcomes from the comparison between RMs and SMs showed discrepancies in total mass reconstruction by the SMs models. The CAMx/PSAT severely underestimates anthropogenic SOA, while GEM-AQ reproduces the opposite situation, but both SMs models overestimated the SIA contribution. For the Traffic source, the EFs are underestimated and all the EI used are missing the contribution of road dust resuspension, which produced a large underestimation of this source contribution by CAMx/PSAT and GEM-AQ models. For the industrial sector, the EFs and the Data activities are very uncertain, so the emissions should be improved. The Residential heating source contributions are generally overestimated, but the bottom-up inventories in Poland allowed improvement.

Objective 2:

During the last decade the estimation of EF for road dust resuspension has improved, but in literature is missing a standard method to estimate that EF. This study aims to compare existing methods available in literature in Milan and Barcelona, which reveals an average uncertainty of 87% attributable to the analytical approach. In addition:

- The spatial variability of emission factors is due to the numerous variables affecting road dust loading: pavement type, fleet type, speed and braking events and input from external sources. In Barcelona, EF varied from 12.7 to 26.3 mg/veh/km among 7 different streets (22% uncertainty), while in Milan the variability was lower among 13 streets, from 15.7 to 27.7 mg/veh/km (14 % uncertainty).

- The temporal variability of EF is related to meteorology (road moisture) and possibly also seasonal changes (mostly in regions where road sanding/salting or studded tyres are used). The meteorological effects occur mostly on an hourly basis in case of precipitation, and can affect heavily the daily and annual-averaged emissions [14].

Objective 3:

The preliminary results concerning the comparison between the two CAMx/PSAT simulations reveal improvements with the implementation of the EFs of RDR: the Po Valley case the baseline simulation using the local EI INEMAR 2017 for the non-exhaust emission showed low time correlation (0.38) between the two models, in the Sensitivity scenario, using the local EI INEMAR 2017 and implemented by the EFs estimation of RDR from objective 2, yielding an improvement in both the absolute contributions and time correlation (0.44).

Acknowledgement:
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Recovery of high value metals from LIBs lixiviates in a complex matrix

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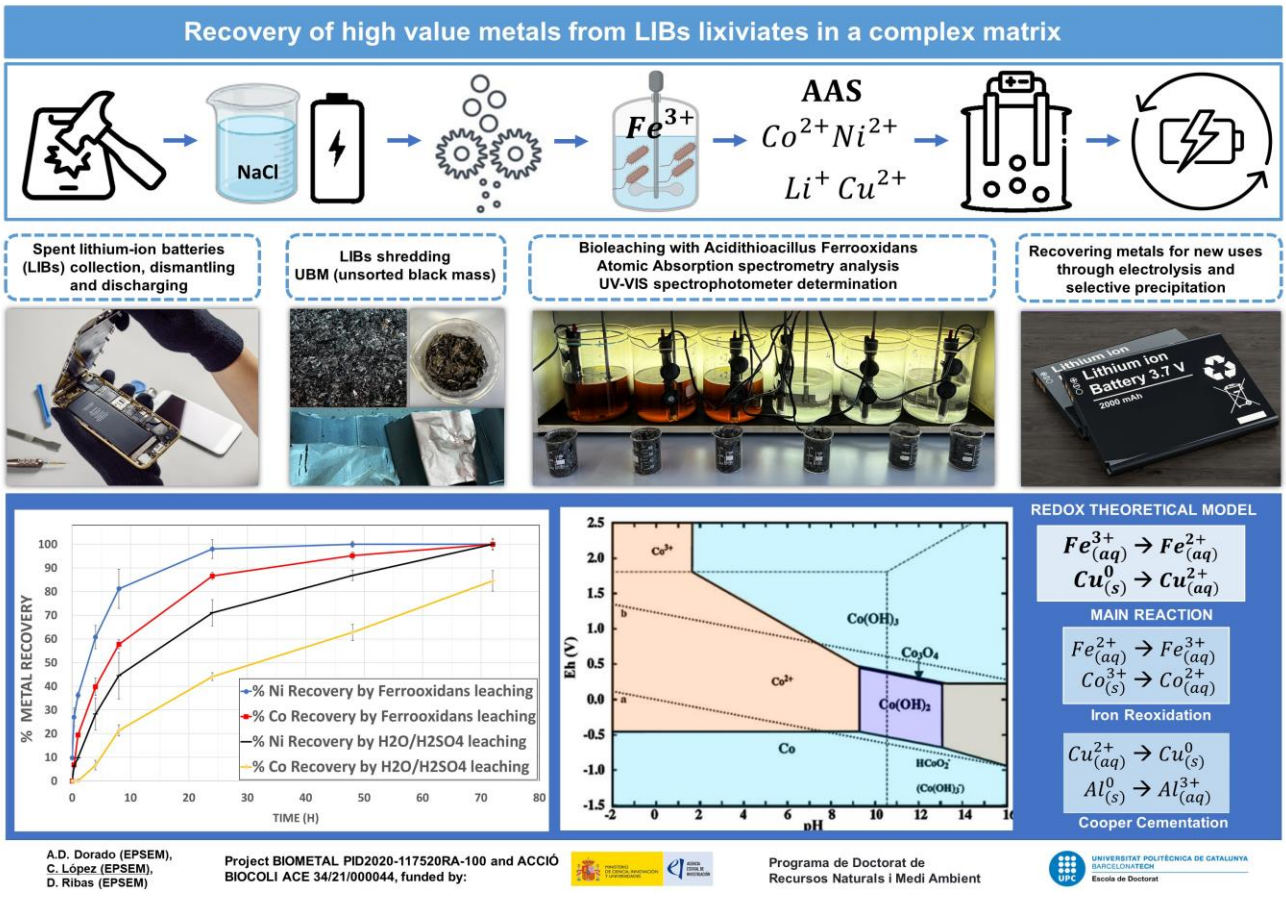
Keywords: bioleaching, lithium-ion batteries recovery, end-of-life mobile phones, waste electrical and electronic equipment, redox stoichiometry

Graphical Abstract



This PhD is being carried out thanks to the Doctorate program of Natural Resources and Environment (UPC), within the study framework of projects BIOMETAL (Development of a smart automated BIObased process for the recovery of valuable metals from end-of-life mobile phones) and BioCoLi (Bioprocess for the recovery of cobalt and lithium-ion batteries).

The bioleaching recovery method for high-value metals such as cobalt, nickel, lithium, copper, manganese and aluminum that are present in end-use lithium-ion batteries will be examined. For this purpose, a study will be conducted to determine the best conditions and methodologies for achieving high concentration rates of these metals in their solved forms. A theoretical model describing the redox reactions of the process will be released. Furthermore, different technologies for separating the metals from the LIBs leachates will be investigated. Therefore, this work aims to analyze and determine the best options for recovering metals present in the complex matrix resulting from a specific metal bioleaching process.

Lithium-ion batteries are crucial for the automotive and tech industries due to their high energy density, safety, high specific capacity, long service life admitting a high number of charging-discharging cycles, rapid charging, lightweight, and low-temperature resilience. These advantages make them ideal for smartphones and electric vehicles, leading to increased usage and waste generation.

The extraction of metals for lithium-ion batteries production, poses environmental and social challenges. Electronic waste contains higher percentages of these metals than natural ores. "Urban mining," which involves reclaiming raw materials from waste products, presents a viable metals recuperation alternative that reduces electronic waste, promotes the circular economy, and addresses global resource shortages.

Currently, the management of waste electronic equipment and the extraction of valuable metals from it remain significant challenges. The initial phase of this research involves the analysis of various technologies for the recovery of spent Lithium-Ion batteries (LIBs). These technologies include pyrometallurgy, hydrometallurgy, electrochemistry, mechanochemical methods, membrane separation, deep eutectic solvent leaching, and other methods, with a particular emphasis on bioleaching processes.

Bio-hydrometallurgical processes, traditionally used for metal recovery from minerals, are also effective for extracting critical metals from electronic waste. This technology is more environmentally friendly than pyrometallurgical and hydrometallurgical methods, operating at ambient conditions (around 30ºC) with significantly lower energy consumption and fewer harmful gas emissions. Consequently, the bioleaching process has lower operating costs, and the metabolic products generated are not environmentally hazardous.

The bioleaching process that will be used in this study has already been patented with number PCT/EP2019/059886 and description: *Method for the biological recovery of metals in electric and electronic waste.* The method is based on the metabolic activity of specific microorganisms to create and regenerate leaching agents, allowing the extraction of main metals from the complex matrix in which they are immobilized in discarded mobile phones. The process uses Fe^{3+} as an oxidant leaching agent, produced by converting Fe^{2+} to Fe^{3+} with the bacterium *Acidithiobacillus*

ferrooxidans under controlled pH conditions. The biogenic Fe^{3+} solution is then applied to electronic waste. During leaching, Cu^0 is oxidized to Cu^{2+}, and Fe^{3+} is reduced to Fe^{2+}. This Fe^{2+} is biologically regenerated into Fe^{3+} in a cyclic process. The procedure operates at a room temperature of 30ºC and ph 1,5.

In the initial experiment, LIBs waste samples obtained from 50 end-of-life mobile batteries were bioleached. The batteries were discharged in a 1% NaCl solution for 48 hours, then shredded with a 7 mm grid, producing the unsorted black mass (UBM) fraction without further sieving. For UBM characterization, a representative sample was obtained by quartering. 30 grams were digested in 300 mL of aqua regia (HCl/HNO3 1:3) at 90°C for an hour. The sample was filtered and diluted with deionized water. Metal concentrations were determined using a Perkin Elmer PINAACLE 500 atomic absorption spectroscopy (AAS) with SYNGISTIC AA software, control system, and autosampler. The UBM composition was determined to be: 11.5% Cu, 17.3% Co, 1.86% Li, 0.82% Ni, and 24.1% Al.

In the bioleaching experiment 50 grams of quartered UBM (pulp density 5% w/v) was introduced in 1 liter of biogenerated Fe^{3+} solution, with an initial iron concentration of 10 g Fe/L (10k). The process was conducted at 30°C, maintained by an immersion probe heater, with continuous stirring. The pH was kept at 1.5, adjusted with 20% H_2SO_4. The experiment and a blank leaching using H_2O were performed in triplicate. Over 72 hours, samples and measurements of pH and redox values were taken at intervals: 0, 20 minutes, 1h, 4h, 8h, 24h, 48h, and 72h. The concentrations of Cu, Co, Li, Ni, and Al were determined by atomic absorption spectrometry, while $Fe^{2+,}$ $Fe^{3+,}$ and FeT concentrations were measured using a Perkin-Elmer Lambda 25 UV-VIS spectrophotometer.

In the *ferrooxidans* bioleaching, the recovery rate for cobalt reached 86% within 24 hours, and nickel achieved nearly 98% in the same timeframe. Both elements reached 100% recovery within 72 hours for cobalt and 48 hours for nickel. In the blank bioleaching with H_2O and 20% H_2SO_4 correction, nickel achieved a 70% recovery rate in 24 hours and 100% in 72 hours, while cobalt reached 44% in 24 hours and 84% in 72 hours. For lithium and aluminium, lower recovery rates were observed: 11% for lithium in 40 hours and 50% for aluminium in 30 hours. The blank bioleaching results were similar. Notably, copper was not recovered.

To better understand the outcomes, the corresponding redox reactions are being studied. Examining the oxidation states of each element in the LIBs waste and in the soluble form is crucial. Copper is found in its elemental form in the discharged battery and is oxidized to Cu^{2+}, its soluble form in the leachate, through reaction with biogenic $Fe^{3+,}$ which is reduced to Fe^{2+}. In Li-ion batteries, the remaining metals are present as metal oxides ($LiCoO_2$, $LiNi_xCo_yMn_zO_2$, $LiMn_2O_4$). Lithium exists as soluble Li^+, while cobalt, nickel, and manganese exist in high oxidation states (Co^{3+}, Ni^{3+}, Mn^{4+}) and need to be reduced to lower oxidation states (Co^{2+}, Ni^{2+}, Mn^{2+}) to become soluble. Therefore, the Fe^{2+} produced during Cu^0 oxidation aids in the reduction of these metals, contributing to the favourable results observed for cobalt and nickel. Regarding the copper results, a cementation process may be occurring due to the redox reaction between aluminium and copper. This process results in the oxidation of Al^0 to Al^{3+} and the reduction of Cu^{2+} to Cu^0, which might explain the lack of copper recovery.

The subsequent phase of the investigation will entail calculating the equivalent electron balance for the redox reactions during leaching. The investigation will focus on the kinetics of each redox pair and the consumption of protons. Therefore, a theoretical model of redox reactions in leaching will be developed with the goal of anticipating reactions based on waste type and establishing adjustments for achieving optimal metal recovery ratios.

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Valorisation of clayey waste for the manufacture of cementitious materials

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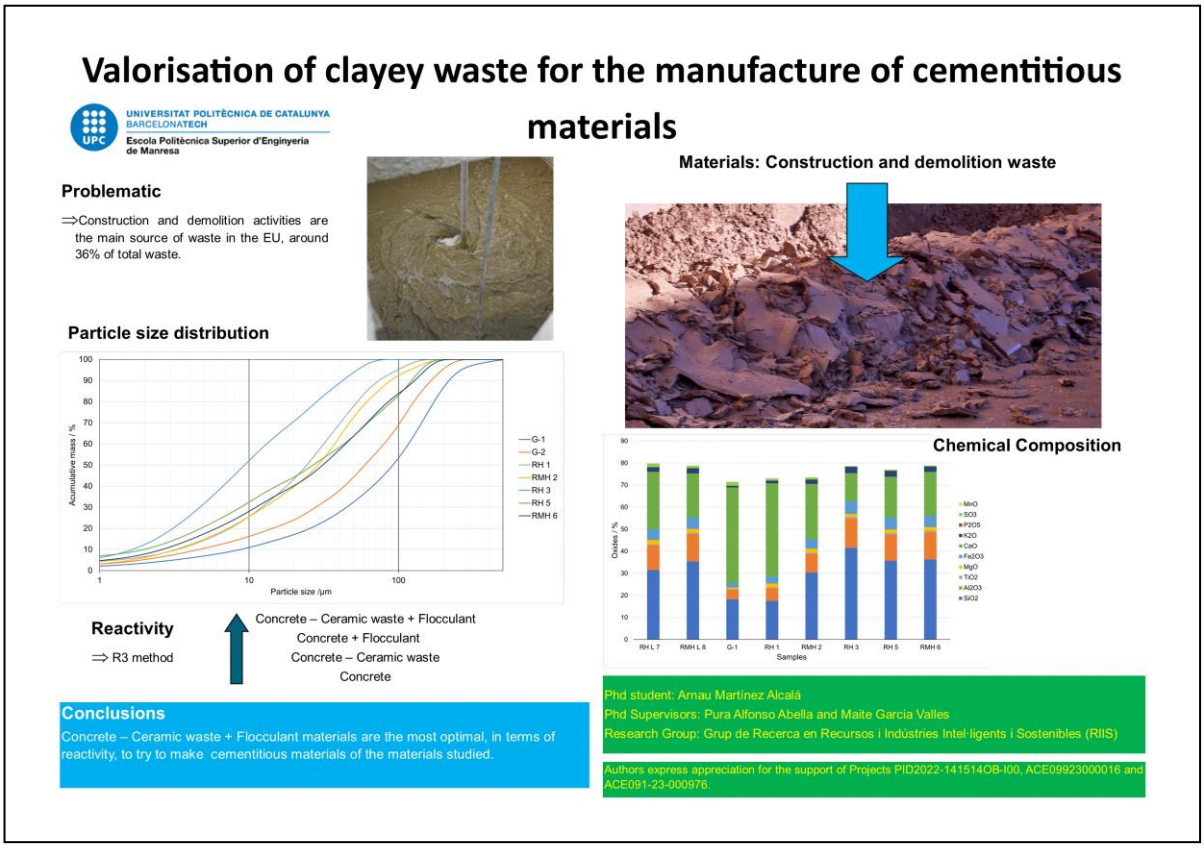
Keywords: Recycle, CDW, Cementitious materials.

Graphical Abstract



Abstract

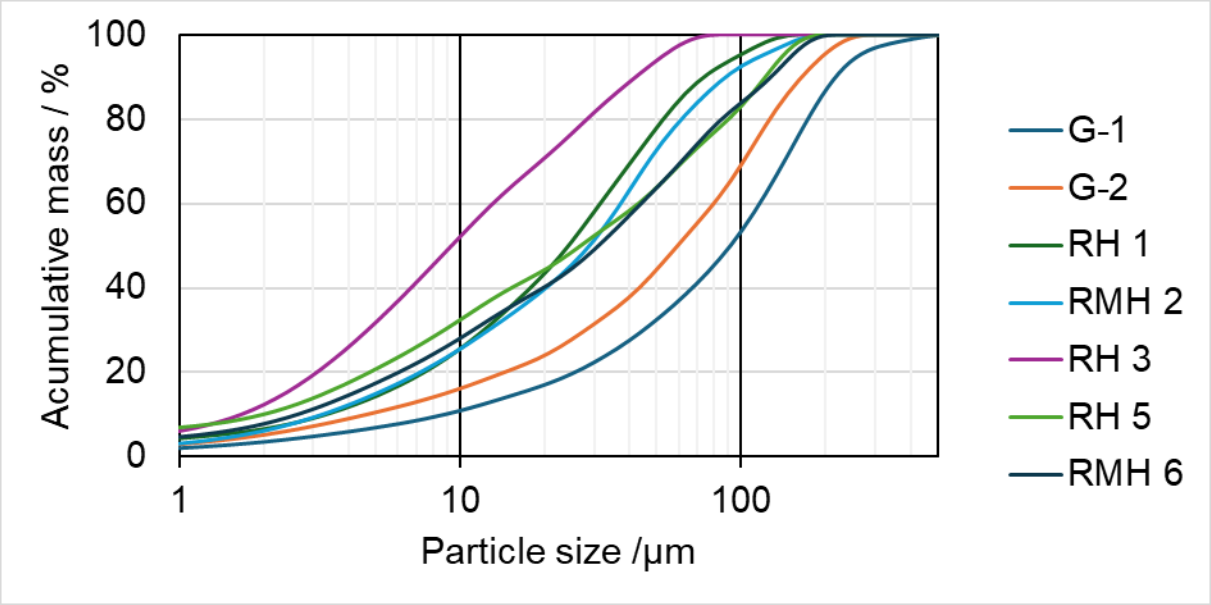
Construction and demolition activities are the main source of waste in the EU, where the construction sector produces around 36% of total waste [1]. In the EU a significant part of this waste is recovered, e.g. the production of recycled concrete aggregates (RCA) is common practice in the Netherlands, where it reaches 99% or Italy and Slovenia, with more than 97%

while Spain has 70.5 %. However, the high recovery rates of construction and demolition waste (CDW) in Europe are mostly achieved by using the recovered waste for practices such as backfilling and low-grade recovery applications, such as the use of recycled aggregates in road sub-bases, which reduces the potential to move towards truly circular waste management [2]. The recycling of the finer fraction (dp<5mm) is particularly problematic as its use as aggregates produces a concrete of lower durability so this fraction is recycled to a very limited extent [3]. The finest waste (dp<150µm) represents 20-30% of the total [4], so a considerable amount remains to be reused.

Due to the growing concern about global CO2 emissions, in recent decades, the total or partial substitution of Portland cement with certain volumes of supplementary cementitious materials (SCMs), which have hydraulic and/or pozzolanic or filler properties, has been proposed, thus decreasing CO2 emissions from cement production. Some of these materials have been extensively researched. However, in recent years, such as granulated blast furnace slag and coal fly ash, which are currently in significant shortage [5]. Therefore, there is a need to explore novel and sustainable CSMs. One option that is recently starting to be investigated is the use of construction and demolition waste for the manufacture of alkali-activated cements, and some positive results have already been achieved [6,7]. CDW has also been considered for recycling into new clinker [8]. Hydrated cement treated at high temperature (600-800 ◦C) can lose its hydration, the same happens with clay minerals, dehydroxylation by heat treatment at 500-900 °C transforming them into amorphous phases, causing the treated materials to exhibit pozzolanic reactivity [9]. Kaolinitic clays show high pozzolanic reactivity after heat treatment, while some other clay minerals (e.g. montmorillonites and illite) show low reactivity or even remain inert after heating [10]. Reactivity has also been found to increase when the residue is intensively milled [4]. The objective of the proposed thesis is to determine the suitability of different types of clayey wastes whose mixtures allow the reuse of the finest fraction of construction and demolition waste for the manufacture of new cementitious materials as a substitute for Portland cement.

For carried out studies, there were used CDW from two recycling plants in Catalonia. In each of them, two types of waste are differentiated: concrete waste (RH) and waste that also incorporates ceramic material (RMH). A granulometric, chemical, mineralogical and thermal characterisation was carried out on all of them, as well as their rheological properties. The particle size of RH and RMH corresponds to 90% below 120µm and 50% below 40µm (Fig.1). Although there is a great variability depending on the demolition, in the chemical composition of the RH, SiO2 reaches up to 30% and CaO up to 35%, while in the RMH, SiO2 is higher and CaO does not exceed 20%. In terms of reactivity, tests have been carried out following the R3 method where a cement is simulated with the residues and the addition of portlandite. The portlandite consumed is evaluated by thermal-differential analysis and thermogravimetry (ATD-TG). The results obtained show that the highest reactivity occurs for the RMH in which flocculant has been added.

Figure 1. Granulometry of CDW fine particles.



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Trends and patterns of tropospheric ozone pollution episodes in Spain

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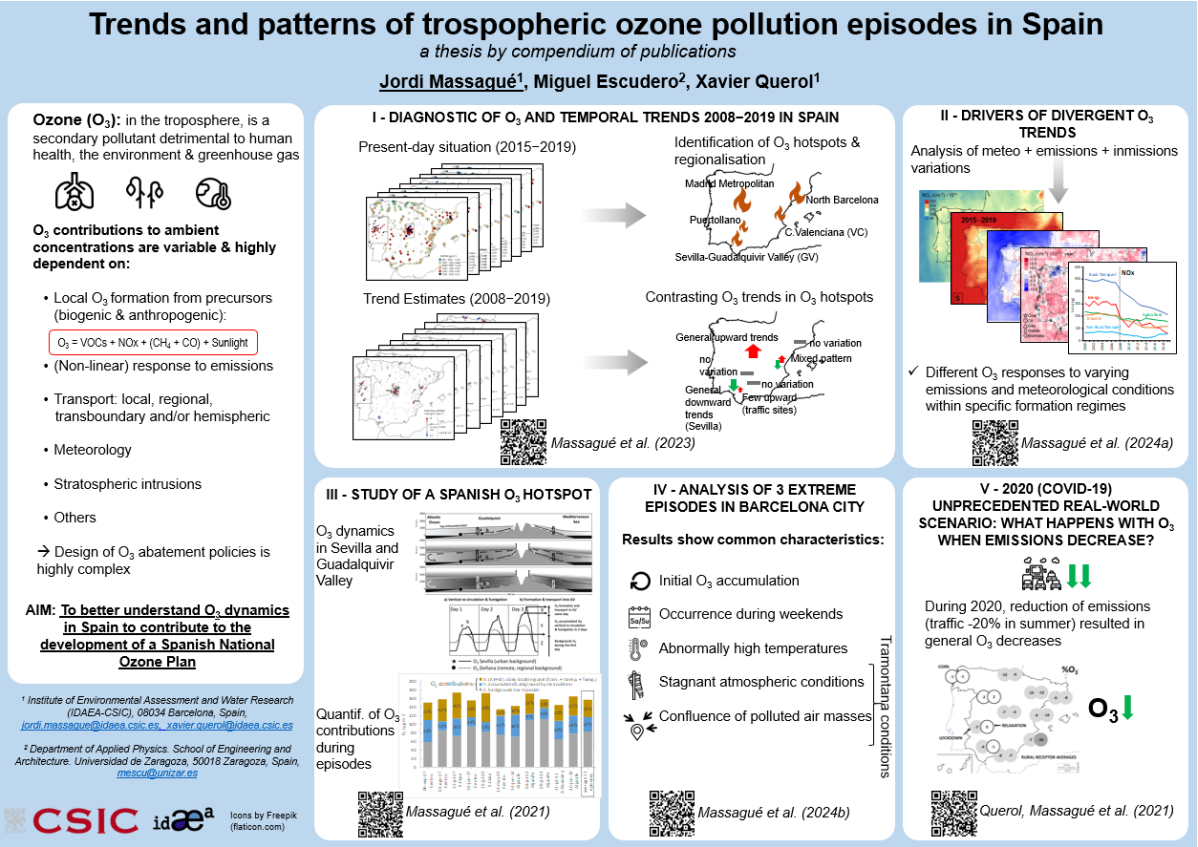
Keywords: Air pollution. Air quality. Time trends. Tropospheric ozone

*References that form part of the compendium of publications in this thesis are in **bold** type*

Graphical Abstract



Tropospheric ozone (O_3) is a potent oxidizing secondary atmospheric pollutant with important effects detrimental to human health, vegetation and materials. O_3 formation is highly dependent on the presence of its precursors (NOx, CH_4, CO, and non-methane volatile organic compounds, VOCs) and solar radiation, as well as specific meteorology and geographical patterns that favour its accumulation [e.g., 1].

O_3 pollution is a major air quality (AQ) concern in Europe, especially in southern and Mediterranean countries. Spain consistently exceeds European AQ limits [2]. O_3 concentrations at a particular location may result from different O_3 contributions, and their relative proportions are highly variable, hence the causes of exceedances of AQ standards can also vary widely. In Spain, high chronic and episodic O_3 concentrations may result from (i) local/regional formation from precursors, sometimes favoured by complex vertical recirculation/accumulation of air masses during summer; (ii) regional or hemispheric transport (of O_3 and precursors) or (iii) stratospheric intrusions, among others [e.g., 3]. These factors can strongly vary in time and space, rendering the design of O_3 abatement policies highly complex.

In the framework of the elaboration of a Spanish National O_3 Plan commissioned by the Spanish Ministry of Environment, **[4]** assessed trends and spatial patterns of several O_3 metrics in Spain to identify O_3 hotspots and study their temporal changes in 2008–2019. This period, framed between two events that strongly influenced the emission of O_3 precursors globally–the 2008 global financial crisis, and the COVID-19 outbreak in 2020, was considered relevant for the assessment of current policy actions. The Spanish O_3 hotspots were the air basins of Madrid, Vic–Barcelona (V–B), the inner Valencian Community, the Sevilla–Guadalquivir (S–GV) and Puertollano; all of them with relevant local/regional O_3 formation during episodes. Results also showed contrasting O_3 trends between these air basins: (i) Madrid recorded most of the national O_3 upward trends and the highest increasing rates; (ii) V–B, the interior of S–GV, and Puertollano showed no variations; (iii) the Valencian Community exhibited a mixed pattern, whereas, (iv) Sevilla was the only Spanish urban area with general decreasing trends.

The investigation in **[5]** used data on key O_3 precursors and meteorological parameters, and attributed these divergent O_3 trends to the effects of varying precursor emissions and meteorological parameters on different O_3 hotspots over the period.

The O_3 dynamics in S–GV, one of the O_3 hotspots, were examined in detail in **[6],** and a new method based on experimental measurements, was proposed to estimate the contributions to O_3 concentrations during acute episodes, including local/regional origin, long-range transport and/or accumulation/recirculation.

The O_3 dynamics in the V–B air basin, another O_3 hotspot, have been extensively investigated [e.g., 7]. In **[8]**, O_3 dynamics in this air basin were further studied using photochemical models and experimental tools to assess three extreme O_3 episodes that occurred in Barcelona city. The results improve understanding and offer insights into predicting future events. All episodes occurred with (i) initial O_3 accumulation in surrounding coastal areas, (ii) on weekends (due to precursor emission changes), and (iii) during extreme temperatures and Tramontana conditions [9], which cause stagnation and convergence of polluted air masses, including European sources.

Finally, the outbreak of the COVID-19 pandemic in 2020 provided an unprecedented opportunity to study in a real scenario the consequences of a reduction in pollutant emissions. In this context **[10]**, studied meteorology-corrected key air pollutants, including O_3 precursors in Spain during 2020, and found general lower O_3 concentrations and mainly attributed them to less road traffic in urban areas during the different confinements of the population associated to the pandemic.

Acknowledgments:

We wish to express our gratitude to the Spanish Ministry of Ecological Transition and Demographic Challenge (Spanish National Ozone Plan) (17CAES010); European Union's Horizon 2020 research and innovation program under grant agreement; the "Agencia Estatal de Investigación" from the Spanish Ministerio de Ciencia e Innovación and FEDER under the projects HOUSE (CGL2016-78594-R) and CAIAC (PID2019-108990RB-I00) for supporting the studies that form part of this thesis. Additionally, we acknowledge the support received from the Generalitat de Catalunya (grants nos. AGAUR 2017 SGR41, AGAUR 2021 SGR 00447)

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Novel hybrid multitask intelligent approaches to generate 3D spatial subsurface temperature mapping and geothermal resource identification in Catalonia, Spain

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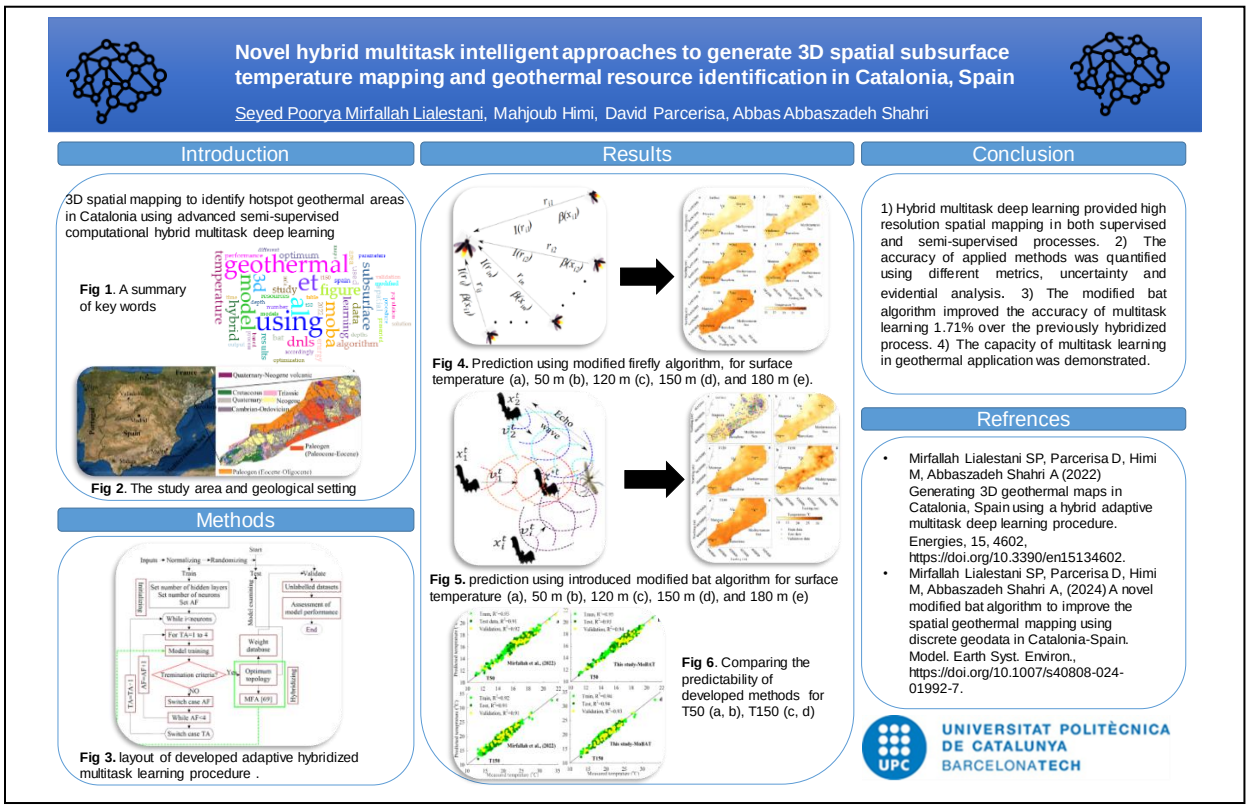
Keywords: 3D spatial map, Catalonia, Geothermal, hybrid adaptive multitask deep learning, Modified bat algorithm

Graphical Abstract



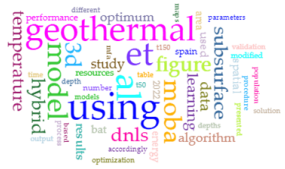


Fig 1. A summary of key words

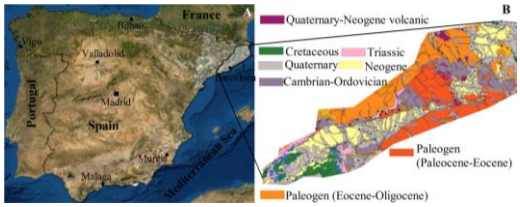


Fig 2. The study area and geological setting

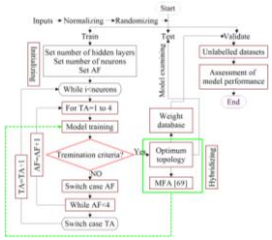


Fig 3. Layout of developed adaptive hybridized multitask learning procedure.

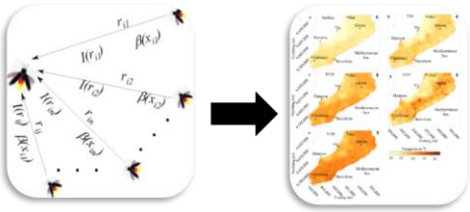


Fig 4. Prediction using modified firefly algorithm, for surface temperature (a), 50 m (b), 120 m (c), 150 m (d), and 180 m (e).

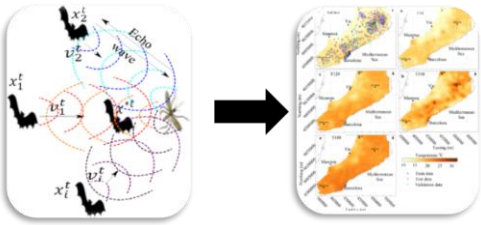


Fig 5. Prediction using introduced modified bat algorithm for surface temperature (a), 50 m (b), 120 m (c), 150 m (d), and 180 m (e)

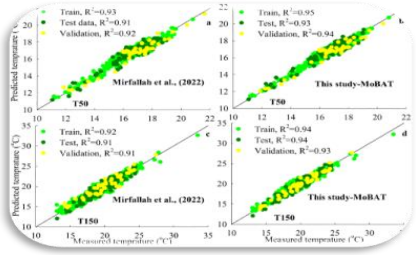


Fig 6. Comparing the predictability of developed methods for T50 (a, b), T150 (c, d)

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Mirfallah Lialestani SP, Parcerisa D, Himi M, Abbaszadeh Shahri A (2022) Generating 3D geothermal maps in Catalonia, Spain using a hybrid adaptive multitask deep learning procedure. Energies, 15, 4602, https://doi.org/10.3390/en15134602

Mirfallah Lialestani SP, Parcerisa D, Himi M, Abbaszadeh Shahri A, (2024) A novel modified bat algorithm to improve the spatial geothermal mapping using discrete geodata in Catalonia-Spain. Model. Earth Syst. Environ., https://doi.org/10.1007/s40808-024-01992-7.

Concentration of quartz from sand deposits for Industrial Applications

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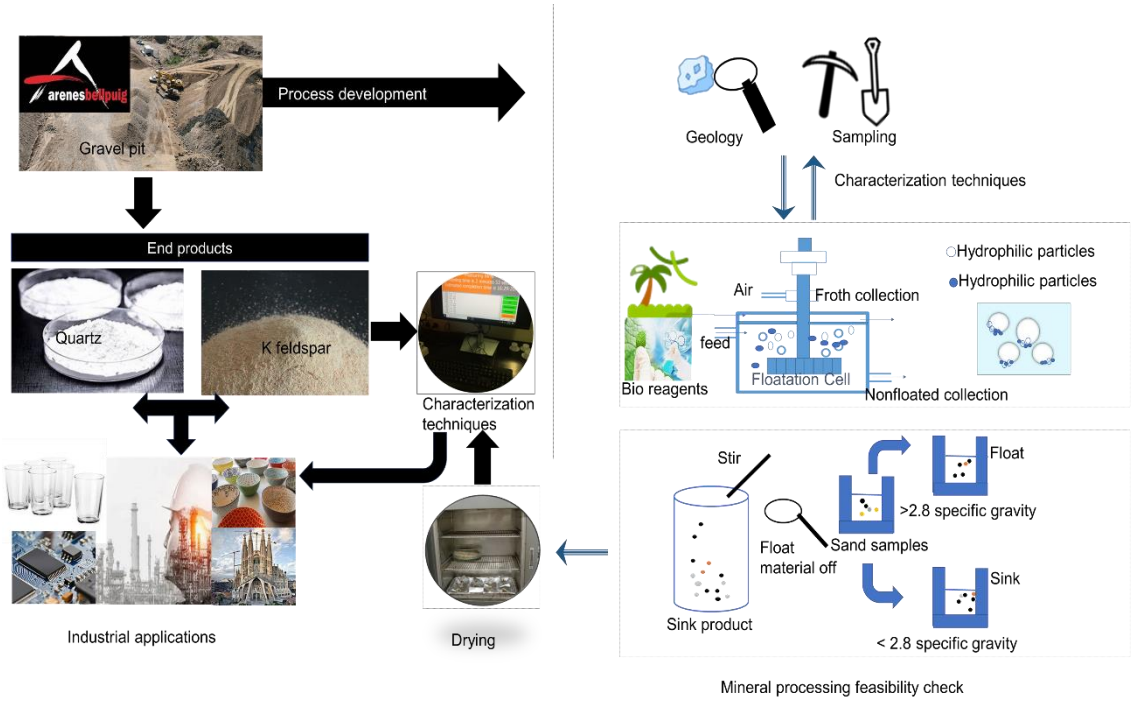
Keywords: Froth flotation, green chemicals, industrial applications, quartz concentration, sand deposits

Graphical Abstract



The impressive increase in silicon metal demand has led to advancements in silica processing for subsequent manufacturing. Before being subjected to the silicon-making process, quartz, the primary source of Silica, is typically purified through mineral processing operation (flotation) in most industries [1].

The conducted studies have examined various flotation reagents, including collectors and depressants, aiming to enhance the recovery process. Many investigations have focused on the flotation beneficiation of silica using low pH conditions. This involves the use of environmentally hazardous acids [2]. The current industrial focus primarily centers on biodegradable chemicals or green chemical solutions, with recent studies emphasizing neutral pH conditions to minimize environmental impact. As part of a systematic approach, this study investigates the flotation

efficiency and interaction mechanisms of two biodegradable ether amines (diamine and monoamine) for the separation of quartz and feldspar from sand deposits [3]. Preliminary flotation experiments have shown that Flotigam 2835-2L effectively separates minerals, particularly at a pH of 9.5, achieving an impressive quartz recovery rate of approximately 85%. However, further analysis of flotation kinetics is necessary to optimize recovery rates even further. This approach presents potential for efficient processing of quartz and feldspar, offering promising avenues for environmentally friendly and economically sustainable practices within the industry.

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Phytoremediation potential of hemp (Cannabis sativa) in soils degraded by gold mining in Zaragoza, Antioquia – Colombia.

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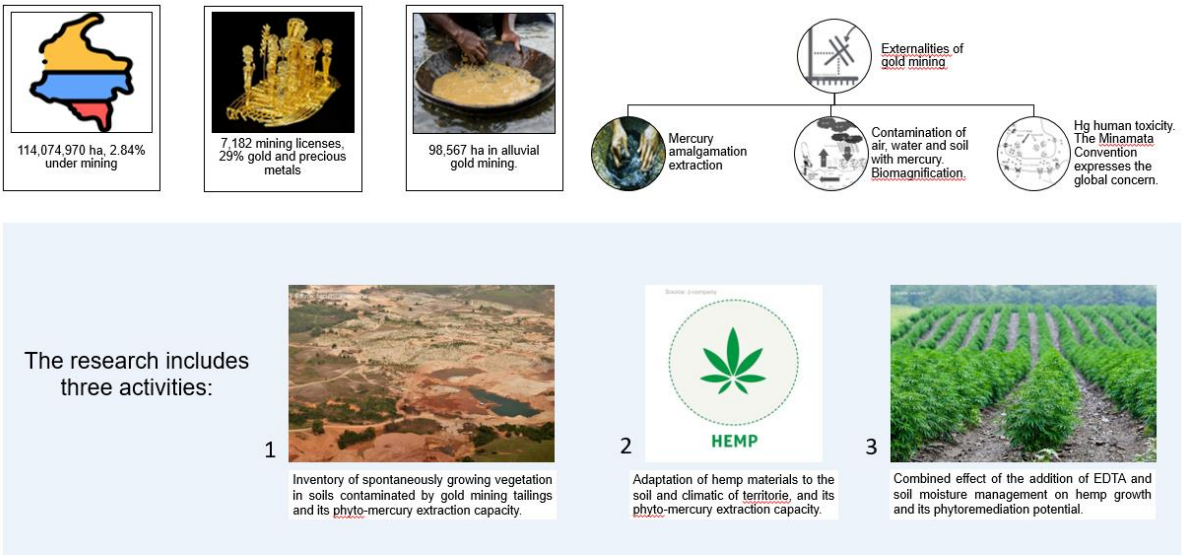
Keywords: biomagnification, gold, mercury amalgamation, phytoremediation, soil sustainability.

Graphical Abstract



The Colombian territory is 114,074,970 ha (1). 2.84% of the surface area is dedicated to mining, the country has 7,182 mining licenses: 29% gold and precious metals (2). In 2022, Colombia produced 51.3 tons of gold, worth USD 2,975 million, equivalent to 18% of the country's mining exports, and 5.2% of Colombian exports (2). Of the 98,567 hectares mined in alluvial gold, 88% are in Chocó, Antioquia and Bolívar. 65% illegal exploitation (3).

In addition to wealth generation, the negative externalities of gold mining for Colombia must be considered. The processing of gold, based on its physicochemical properties, uses gravimetric and mercury amalgamation methods (4), in the second case, about 15 g Hg. g Au produced-1 are used (5). In the management of Hg-Au amalgam, mercury is spilled into bodies of water, before being burned in the open field, releasing Hg in the form of vapor into the atmosphere (6).

The change of the species from inorganic form (Hg^{2+}) to methylated forms (CH_3Hg^+ and $(CH_3)2Hg$) is the first step in bioaccumulation (7,8,9), biomagnification (10,11), and human

toxicity (12,13). The Minamata Convention expresses global concern about mercury exposure (14).

The accumulation of heavy metals in the soil and their potential transfer to agricultural crops poses a risk to human health. Soil remediation includes physical, chemical, and bioremediation processes (including phytoremediation). The ability of the *C. sativa* plant to accumulate heavy metals from the soil is known, this constitutes a double face: risk when looking to take advantage of the resin of the flowers in the pharmaceutical industry, and benefit when it is cultivated for phytoremediation of intoxicated soils.

The objective of this work is to evaluate the phytoremediating potential of hemp materials in gold-mining soils contaminated with mercury in the municipality of Zaragoza (Colombia). The research includes three activities:

- Inventory of spontaneously growing vegetation in soils contaminated by gold mining tailings and its phyto-mercury extraction capacity (15, 16).

- Adaptation of hemp materials to the soil and climatic supply of mining territories of the municipality of Zaragoza, Antioquia and its phyto-extraction capacity of mercury from the soil (17, 18).

- Combined effect of the addition of ethylenediaminetetraacetic acid (EDTA) and soil moisture management on hemp growth and phytoremediation potential (19, 20).

The determination of the total plant and edaphic tissue mercury content will be done with the DMA-80 direct mercury analyzer, following the EPA7473 reference method, with results expressed in mg. g-1, in the laboratories of the Unilasallista University Corporation in Antioquia.

Acknowledgment:

Authors express appreciation for the support to: National University of Colombia. Coordination of Mines and Environment of the municipality of Zaragoza, Antioquia. Gold mine The Amada, Zaragoza, Antioquia.

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Development of an integrated biological base process for the recovery of strategic metals from electronic waste

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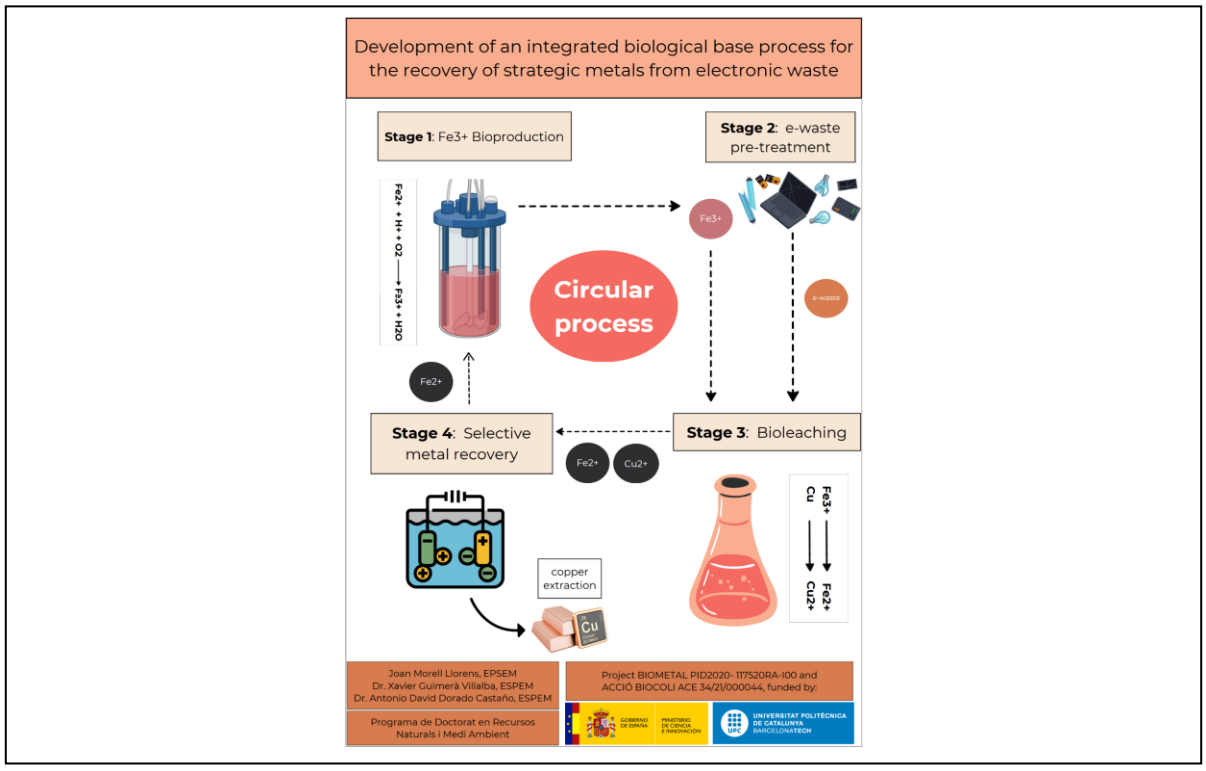
Keywords: Acidithiobacillus ferrooxidans, bioleaching, circular economy, e-waste, O2 transfer



Abstract

In today's world, due to the massive use of electronic devices, electronic waste (e-waste) streams are experiencing the fastest acceleration among solid waste streams (Yaashikaa et al., 2022). Global production of electronic waste reached 52.2 million tons in 2021 and it is estimated to achieve 74 million metric tons in 2030 (Forti et al., 2020).

The conventional techniques available for metal recovery from e-waste are pyrometallurgical and hydrometallurgical. Still, both methods have been disadvantageous due to their severe environmental impact, the production of secondary pollutants, high energy inputs, and chemical

reagent consumption (Magoda et al., 2024). However, both processes dominate the literature and industrial implementation of e-waste end-processing (Li et al., 2019).

As an alternative to pyrometallurgical and hydrometallurgical processes, bio-hydrometallurgy is a new, cleaner, and one of the most promising eco-friendly technologies. Bio-hydrometallurgy or bioleaching is based on the use of certain microorganisms whose activity results in metabolites capable of extracting specific metals. Metal dissolution and recovery by microorganisms have many advantages over other recycling technologies such as environmentally safe, less harmful gases emitted, low operational costs, and low energy inputs (Roy et al., 2021).

The main objective of this doctoral thesis is the study, characterization, and optimization of a biological process to recover metals from e-waste. This biological process consists of four stages. The first stage involves the production of the lixiviant agent (Fe^{3+}) using Acidithiobacillus ferrooxidans. The second stage involves a pre-treatment of electronic waste to concentrate the metals of interest. The third stage consists of the bioleaching of metals from e-waste, and finally, the last stage involves the solid-state recovery of bioleached metals. To achieve the main objective, a series of specific objectives (SP) for each of the four stages have been set, which are as follows:

SP 1: Study oxygen limitation in the bioproduction of Fe^{3+} and propose intensive aeration methods.

SP 2: Characterize mobile phones and batteries based on granularity.

SP 3: Design a non-invasive color sensor to monitor the relationship between Fe^{2+}/Fe^{3+} and the concentration of Cu^{2+}

SP 4: Selective recovery of metals through electrolysis

Finally, the ultimate goal (**SP 5**) is to continuously integrate the previously developed stages into an optimal, cyclical, and automated operating system, which includes a comprehensive technical and economic evaluation of the process to determine its feasibility on an industrial scale.

So far, SP1, SP2 and SP3 have been achieved. The results obtained from these three specific objectives are shown below

SP1: Improving the transfer of dissolved oxygen in a biological Fe^{2+} oxidation process using a venturi jet as an intensive aeration system

With this study, by monitoring the oxygen concentration in a fixed biomass system with *A. ferrooxidans*, it was determined that the Fe^{2+} oxidation rate was limited by the dissolved oxygen concentration. Consequently, an intensive aeration system, a jet venturi, was designed to improve oxygen transfer. As a result, the system was no longer limited by oxygen concentration, and the oxidation rate increased 3.5 times, from 9.09 to 27.01 g $Fe^{2+}/(L \cdot h)$, as can be seen in **¡Error! No se encuentra el origen de la referencia.**.

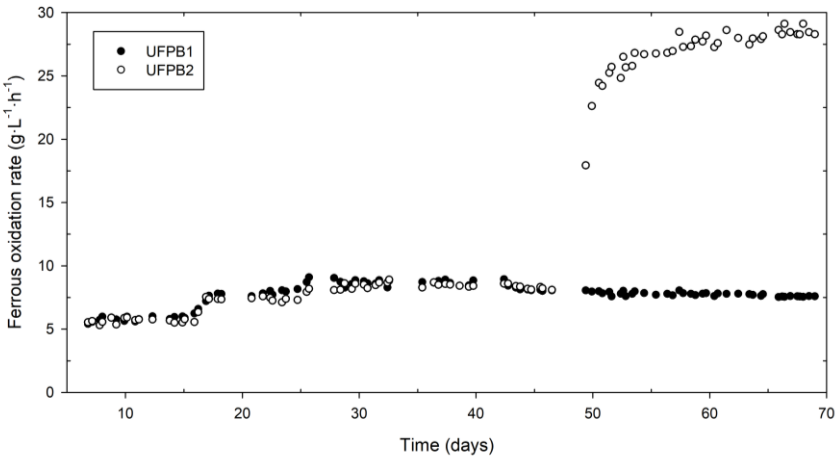


Figure 2: Evolution of the ferrous oxidation rate aerating with diffuser in both reactors and with jet venuturi from day 49 on reactor UFPB2.

SP2: metals liberation and concentration through Pre-processing of smartphones mill shredding and screening-sieving for recyclable

In this study, a complete characterization of different particle sizes from mobile phone bodies and batteries with the minimum manual dismantling was performed. Only the back covers and batteries have been removed for security reasons, while PCBs, screens, plastics, speakers, or cameras were not separated. This methodology contrasts with the most available literature, where most complex separations, even component by component, were carried out (Anshu Priya & Hait, 2018; Bookhagen et al., 2020; Sahan et al., 2019).

For instance, results showed that in mobile phones, Al, Fe, Zn, Ni, Mn, Cr, and Nd are concentrated in the larger fractions, while Li, Ag, Pd, and Pt are concentrated in the smaller fractions.

SP 3: Design of an RGB-Arduino Device for Monitoring Copper Recovery from PCBs

When Fe^{3+} comes into contact with electronic waste, redox reactions occur, where Fe^{3+} is reduced to Fe^{2+} and the metals are oxidized, such as metallic copper being oxidized to Cu^{2+}. During these reactions, a color change occurs in the solution, as shown in **¡Error! No se encuentra el origen de la referencia.**. With this study, a non-invasive color sensor was designed, meaning it does not come into contact with the solution, which could estimate the concentration of Fe^{3+} and Cu^{2+} based on the color of the solution. This way, simply by observing the color of the solution, one could determine if the reaction has completed.

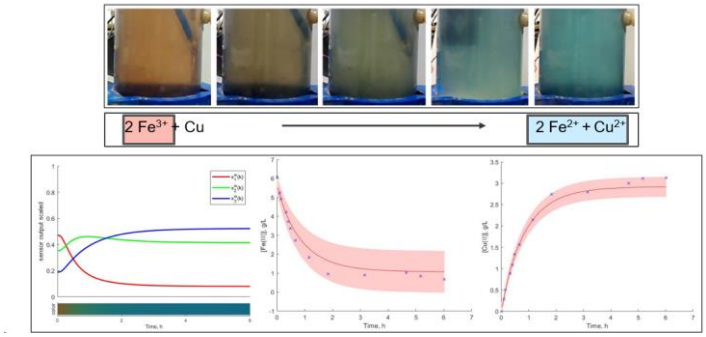


Figure 3: Variation of the solution color in the reactor during oxidation and reduction reactions and adjustment of Cu^{2+} and Fe^{3+} concentrations in the color sensor.

Acknowledgment:

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The Forest and sustainability Project

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Keywords: Citizen Science, Forest, Open Science Schooling, Secondary School, Sustainable Development Goals

Introduction

The Forest and Sustainability project aims to link the Sustainable Development Goals using the forests as a common thread [1], by studying the immediate surroundings of students, home, town or county. Participants take part in several activities they can complete online using open-source software, from all social backgrounds, urban and rural communities. The project is a Citizen Science and Open Science Schooling [2] with several stakeholders involved. The participants (12 to 18 years old) study the water and air quality in their area, and realize that their daily water and energy consumption— electricity, heating and transport— can be reduced with a simple change of habits (Fig. 1). With the data collected, they can evaluate whether there are sufficient green spaces nearby and assess the level of pollution they are exposed to. This means that students ask themselves questions, which they alone cannot answer, and force them to interact with the community: family, public administration, companies...

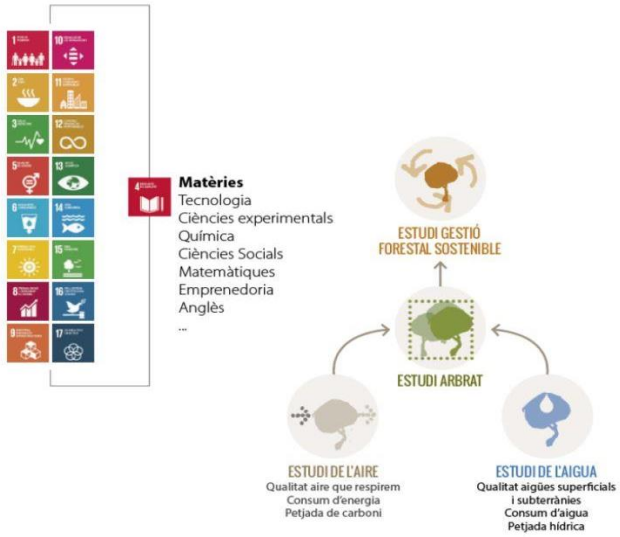

Figure 1. Abstract of the Forest and sustainability project.

In three editions, the project has been implemented in 60 Secondary schools in Catalonia, 110 teachers involved and 1.200 student participants. Most of the teachers who take part are eager to repeat the experience with new students (Fig.2)

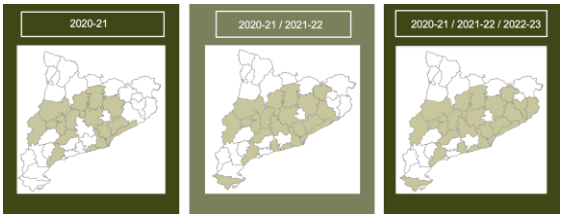

Figure 2. Distribution of participants in Catalonia.

Methodology

For the preparation of the project the teachers attend a training course that allows the project executors to be co-creators and provide feedback. The participants use 6 Activity documents (Fig.

3). Research questions are: Is the Forest and Sustainability Project an effective and efficient learning activity for acquire knowledge about the SDGs?

Do participants change their views on sustainability issues once the project is over? To address the research questions, we utilized a quasi-experimental study with a pretest–posttest design. We measured students' responses before and after engaging the project. We used a Likert-scale questionnaire appropriate, as this kind of instrument is commonly used in the literature. In addition, a questionnaire is carried out among the participating teachers.

Results

Below are the flow diagrams obtained in analyzing the responses of the students who have participated in all three editions 2020-2023.

Figure 3. Activity documents.

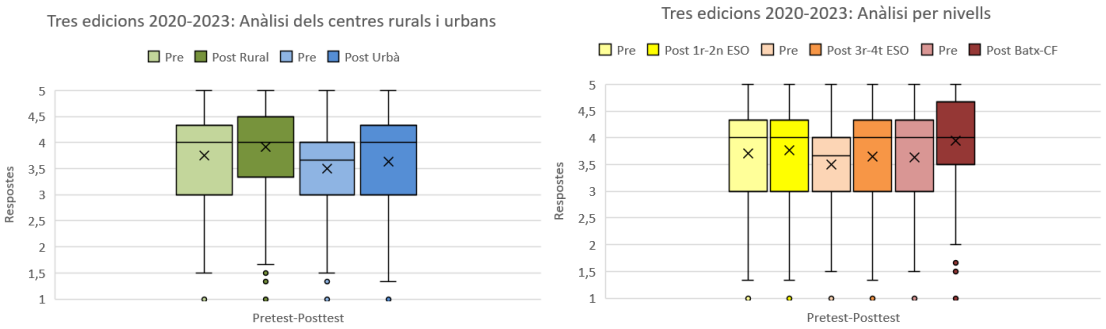

Figure 4. Analysis of data by type of center (left) and by educational level (right).

In the analysis of the data classified by type of center in rural centers and urban centers (at left), it is possible to make the following observations: in general terms, the answers give higher ratings in rural centers than in urban centers. Both in the pretest and in the post-test, in rural centers the mean and median are higher than in urban centers. On the other hand, the impact of the project is greater in urban centers, since the difference between the pretest and post-test is more significant. At right, the answers are presented classified into three educational levels: 1st and 2nd courses of ESO, 3rd and 4th courses of ESO and baccalaureate and cycles. It is possible to make the following observations: in general terms, the responses from 1st and 2nd ESO students give higher ratings than the responses from 3rd and 4th ESO students. On the other hand, the impact of the project is greater and there is more difference between the post-test and the pretest in a measure that increases the educational level. The baccalaureate and the cycles courses are where there is more of a greater impact of the project.

Knowledgment:

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Advanced treatment schemes of petrochemical industrial wastewater for its reuse as cooling water

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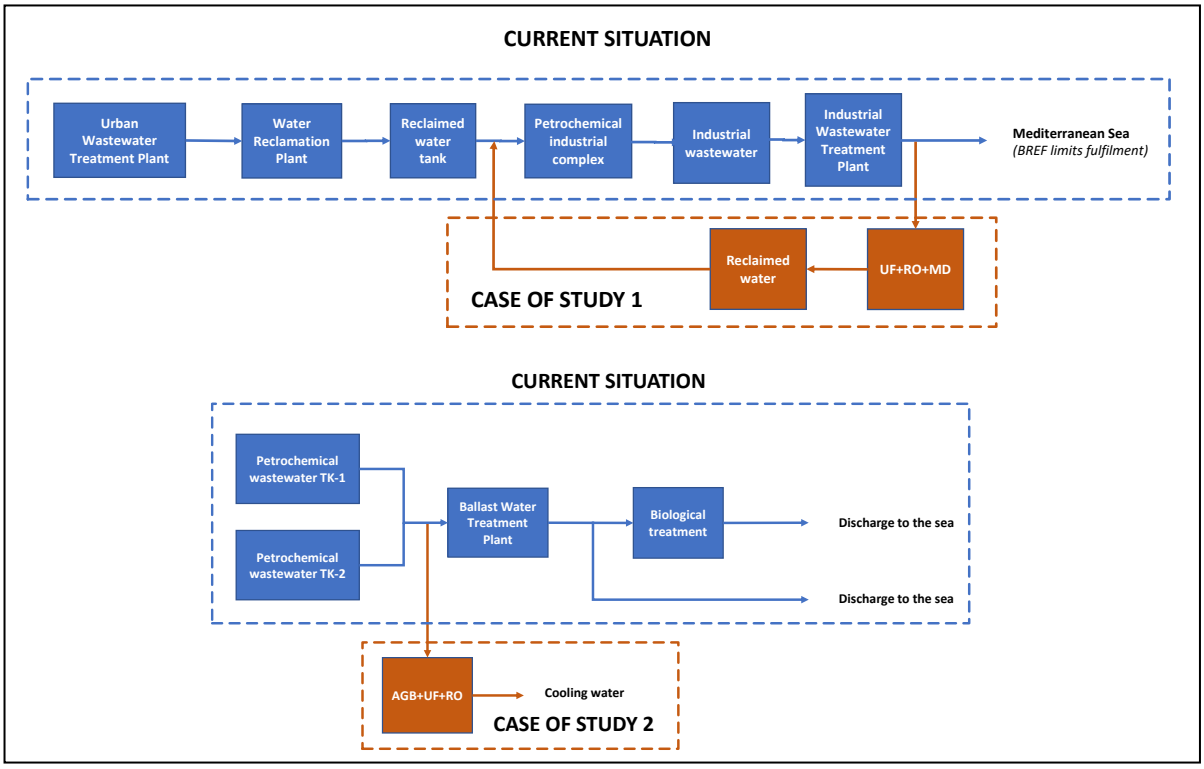
Keywords: granular biomass, near-zero liquid discharge (nZLD), petrochemical wastewater, reclaimed water, regenerated membranes.

Graphical Abstract



Abstract

As an important natural resource, water is an indispensable resource for human life and production. It is of great significance for promoting social and economic development and promoting the progress of civilization. At present, the world is facing a serious water resource crisis, and a quarter of the world's population is facing water shortages. In order to alleviate the water crisis, the recycling of industrial wastewater has become an important way to solve the water crisis, alleviate the shortage of water resources, and increase the supply of water resources (Zhang et al. 2022).

Annual water consumption in the world amounts to roughly 3900 cubic kilometers, of which a total of 18% is used by industrial activities (Hansen et al. 2018). Water is a key resource for the operation of chemical and petrochemical production processes. For example, in petroleum production and processing units, nearly 6 cubic meters of water are used for each cubic meter of processed petroleum (Hansen et al., 2019). Distillation, liquid-liquid extraction, washing operations and cooling systems are some examples among the various processes that use water intensively in these industries.

Due to the need to preserve water resources, employment of reused water is an important and strategic step in achieving sustainable development, particularly in light of potential environmental, economic and social benefits that can be achieved. The adoption of consumption optimization measures and water reuse in industries are estimated to reduce consumption by 25-30% in comparison to this sector's current consumption levels (Hansen et al. 2018).

This paper studies different treatments of industrial wastewater from the petrochemical industry for reuse, primarily, as cooling water. The research is focus on two different industrial cases of study, one located in Spain and the second located in Turkey.

Case of study 1 (Spain): Treatment of industrial effluent to obtain reclaimed water for reuse as cooling water in the petrochemical industry.

This initiative aims to reclaim water treating the industrial Wastewater Treatment Plant (iWWTP) outlet stream from the petrochemical complex, thereby establishing a novel industrial water source for the petrochemical companies. This stream was analytically characterized, showing average values of 7.8 pH, 17,083 mS/cm conductivity, 17 mg/L suspended solids, 23 mg/L COD and 3 mg/L ammonium. Furthermore, Langelier Saturation Index was calculated, showing a scaling tendency.

In this case study, a pioneering approach involving near-zero Liquid Discharge (nZLD) technologies, which integrates ultrafiltration (UF), advanced reverse osmosis (RO) and membrane distillation (MD), will be demonstrated at pilot plant scale.

Simultaneously, a cost-effective treatment methodology utilizing zeolite (Z) adsorption will be showcased. This innovation is targeted at removing ammonium from the existing urban wastewater reclamation plant (WWRP), with the overarching goal of reducing current production costs associated with reclaimed water and augmenting the overall water yield of the system.

Preliminary results indicate that reclaimed water with the required quality can be obtained through ultrafiltration (UF) and a two-stage reverse osmosis (RO) process, obtaining conductivity levels lower than 40 mS/cm and ammonium concentration lower than 0,8 mg/L.

Case of study 2 (Turkey): Treatment of petrochemical process wastewater for its reuse as cooling water.

The primary objective of this initiative is to effectively treat the combination of two different wastewater qualities, ultimately yielding water suitable for internal reuse, such as for cooling or firefighting purposes. The key breakthrough lies in the evaluation of a granulated biomass aerobic reactor for the removal of toxic and persistent pollutants from the wastewater, coupled with the

utilization of regenerated RO membranes to reduce conductivity concentration in the reverse osmosis process.

Initially, both streams were analytically characterized.

Table 1. Stream 1 and stream 2 analytical characterization

Parameter	Unit	TK-961	TK-967
pH		7,1	10,3
Conductivity	mS/cm	1,8	21,7
Total Suspended Solids	mg TSS/L	30,3	49,3
Total Dissolved Solids	mg TDS/L	1172	15626
Total Solids	mg TS/L	1202	15675
Volatile Suspended Solids	mg VSS/L	27	21
NH4-N	mg/L	3,1	6,4
Sodium	mg/L	90	5050
Chemical Oxygen Demand	mg COD/L	150	7346
Oil and greases	mg/L	26	80,5
Phenol	mg/L	0,51	2,03

At the laboratory scale, tests began with an organic loading rate of 0.1 kg/m³ per day. After 97 days of operation in sequential batch mode, biomass granulation was achieved at a treatment rate of 0.8 kg/m³ per day. By the end of this period, the results were as follows: 92% COD removal, 72% phenol removal, and 92% ammonium removal.

Acknowledgment:

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Mineral processing optimization of Li-minerals in las Navas pegmatite deposit

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Keywords: AMICS, Extraction, Lithium, Recovery and Spain

Introduction

Recently, lithium consumption increased significantly due to the high production of rechargeable lithium batteries. Moreover, other end-use markets for lithium were also ceramics and glass, lubricating greases, continuous casting mold flux powders, air treatment, medical products, and others. Actually, worldwide production increased 21% and the global consumption 40% from 2021 to 2022. Therefore, lithium supply security has become a top priority for technology companies, with different strategic alliances and partnerships between technology and exploration companies to ensure the production of this mineral. Mine production is led by Argentina, Australia, Brazil, Canada, Chile, China, Portugal, Zimbabwe with 129.200 tons in 2022. Regarding the world resources, they are mostly distributed in south America with more than 52 million of tons; USA 12 million tons; Australia 7.9 million tons; China, 6.8 million tons. And more specifically, in the Iberian Peninsula 320,000 tons in Spain and 270,000 tons in Portugal. [1]

The collective agreement is that we are living the lithium revolution as a result of the enormous importance of this metal for the green economy transition. Nevertheless, the geographical distribution of lithium resources is not uniform, as it was mentioned before, which entails a high import European dependence of these materials due to the limited presence of critical raw materials (CRM) in the UE. [2] Despite of this, a geological compilation of European lithium hard-rock has proven that lithium is well represented in different deposit types related to several orogenic cycles from Precambrian to Miocene ages across Europe. About thirty hard-rock deposits have been identified, mostly resulting from endogenous processes such as granitic pegmatites in Portugal, Ireland, Finland and Spain. [3] In the central Iberian Zone between Spain and Portugal, Li-mineralization is commonly associated with pegmatites and alkaline granites. Las Navas is a pegmatite deposit, where the main Li minerals are Li-Muscovite, Montebrasite and Spodumene (Spd) related to other mineral species including quartz (Qtz); Feldspar/Lepidolite (Lpd); Topaz (Tp); Cassiterite and Nb-Ta oxides.[4]

The aim of this study is to determine the process mineralogy and to optimize the lithium recovery from pegmatite deposits, more specifically in the case of Las Navas (Cáceres, Spain), where is going to be located the first integrated battery project of the Southern Europe. [5]

Materials and Methods

The preliminary studies were carried out using 15kg crushed sample from Las Navas that was prepared by Freiberg University of Mining and Technology (TUBAF). Here, the sample was separated by wet sieving, and the resultant size fractions were chemically analyzed by portable x-ray fluorescence (XRF). Later, the weighted average of the different fractions was compared with a representative sample to ensure the results. The results were analyzed with the t-student distribution at a confidence level of 99.75%. For the mineralogical composition, X-ray powder diffraction (XRD) was performed. Scanning Electron Microscopy - Energy Dispersive X-ray spectroscopy (SEM-EDS) was carried out to observe the textures and the qualitative composition of the minerals. Finally, quantitative mineralogy was performed using the Advanced Mineral Identification and Characterization System (AMICS).

On the other hand, 56 extraction samples from Lithium Iberia company, owner of Las Navas, were analyzed separately using XRF, XRD, ICP-OES, Electron probe X-ray microanalysis (EPMA), laser abrasion and optical microscopy to obtain a chemical variation and significance map of micas from the mine. Finally, some density separation tests were performed to achieve a concentrate of the Li-mineral species.

Results

The preliminary results of the present research indicate that the chemical composition is highly rich in Lithium due to the concentrations of other rare alkali metals such as Rubidium (up 1000 ppm) and Cesium (around 200ppm) (Table 1).[6] Following the references, the major minerals are Albite (Al), Lpd, Muscovite (Ms), Amblygonite (Aby)/ Montebrasite, Spd and minor Tp and Cassiterite (Table 2). The presence of the Li-minerals was also confirmed by the lilac color of prismatic or wedge-shaped crystals of Li-mica present in the sample. [4] From the AMICS software, the particle and grain-size distribution were obtained, which show that the 60% of grains from Li-minerals are under 40 µm (Figure 2). Furthermore, the liberation of the Li-rich particles shows that after crushing the sample under 100 µm more than 78% of Aby is liberated; 60% of Lpd; 65% of Spd; 45% of petalite (Ptl) (Figure 3).

Conclusions

In conclusion, the pegmatite deposit of Las Navas has a huge variety of Li-minerals worthy to recovery, such as Lpd, Spd, Aby and Ptl, after crushing under 100 µm. Density separation is achievable, but further investigation is required to optimise concentration parameters.

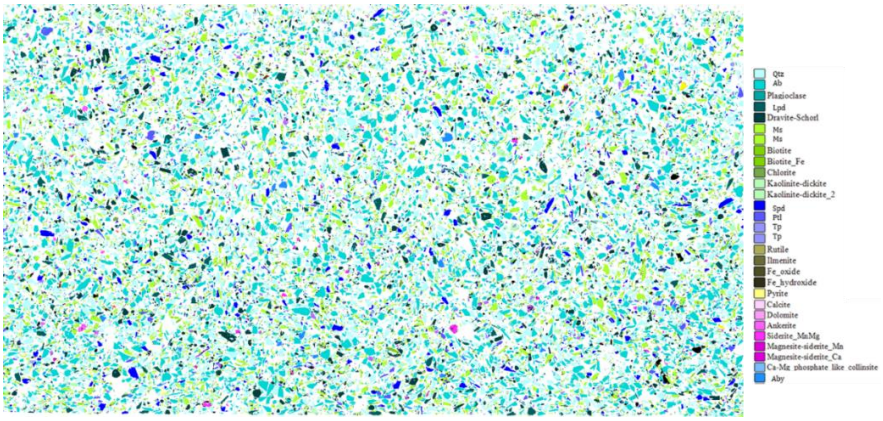

Figure 1. Map of the mineralogy obtained by AMICS of the (20-100) µm fraction.

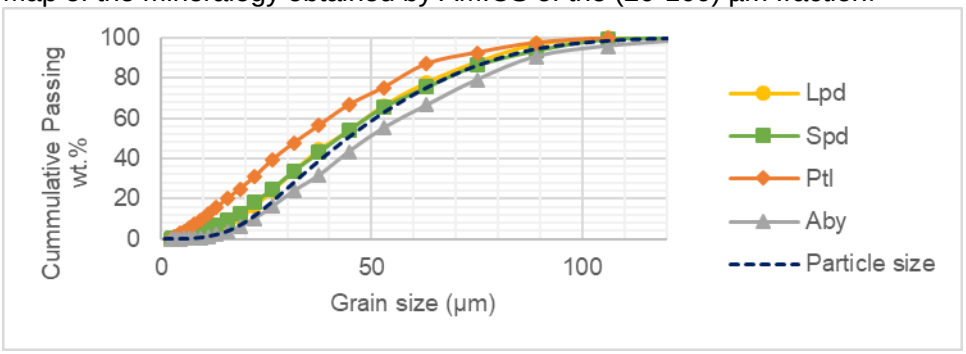

Figure 2. Particle and grain size of the Li-minerals of the preliminary sample (20-100 µm).

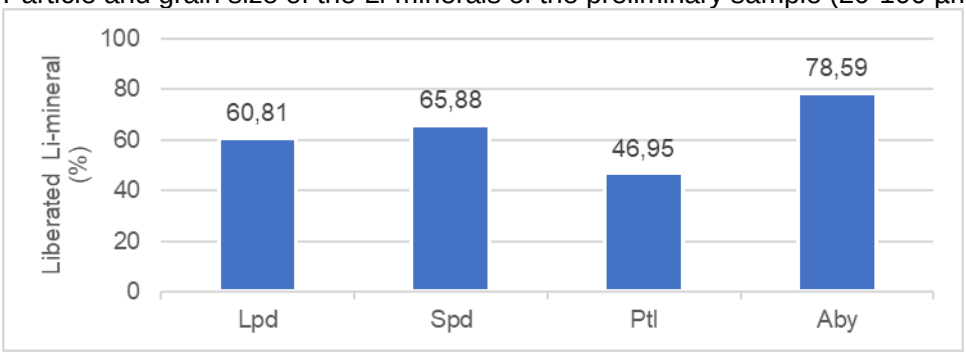

Figure 3. Liberated Li-Minerals of the Li-minerals of of the preliminary sample (20-100 µm).

Table 1. Chemical composition of Las Navas sample by size range analyzed with the t-student distribution at a confidence level of 99.75%.

	<0.1mm 5%	0.1-0.5 mm 11%	0.5-1 mm 9%	1-2 mm 19%	2-3 mm 26%	>3 mm 29%	Las Navas	Las Navas Total	εr (%)
%									
SiO_2	67,45	69,89	71,39	70,71	70,70	69,73	67,81	70,22	-3,56
Al_2O_3	21,00	20,94	19,93	20,72	20,69	20,71	20,44	20,67	-1,15
TiO_2	0,31	0,17	0,16	0,20	0,19	0,26	0,24	0,21	12,18
Fe_2O_3	2,91	1,40	1,30	1,52	1,59	2,11	2,07	1,75	15,40
MgO	1,24	0,96	0,87	0,85	0,68	1,12	1,21	0,92	24,06
CaO	0,97	0,71	0,57	0,60	0,57	0,73	0,73	0,66	9,31
K_2O	3,20	2,99	2,83	3,12	3,10	3,08	3,14	3,07	2,35
P_2O_5	1,90	1,72	1,58	1,57	1,78	1,78	1,81	1,72	4,85
Cl	0,18	0,07	0,07	0,07	0,07	0,06	0,06	0,07	-21,93
ppm									
Rb	1167	1080	1053	1100	1160	1043	1130	1097	2,95

Cs	197	142	131	168	176	176	197	168	7,55
Cr	260	89	23	27	30	63	260	57	47,66
Mn	602	373	342	370	428	420	602	410	-1,52
Co	103	42	41	46	48	63	103	54	12,50
Zn	422	181	131	139	149	147	422	163	-2,95
Ga	187	50	33	35	34	35	187	44	30,84
As	112	76	129	27	69	71	112	70	-19,17
Sr	113	79	76	69	79	89	113	82	-2,45
Zr	114	45	54	54	75	78	114	69	1,98
Sn	515	511	375	404	268	252	515	339	5,36
Ba	128	63	64	88	81	92	128	85	13,67

Table 2. Mineralogical composition of the studied Las Navas material.

Compound Name	Chemical Formula	Semi Quantification (%)
Albite	$Na\ (Al\ Si_3\ O_8)$	37
Muscovite	$KAl_2\ (Si_3Al)\ O_{10}\ (OH)_2$	18
Lepidolite	$K\ (Li,\ Al)_3\ (Si,\ Al)_4O_{10}(F,\ OH)_2$	16
Amblygonite/ Montebrasite	$(Li,\ Na)\ AlPO_4(F,\ OH)$/ $LiAl\ (PO4)\ (OH)$	13
Quartz	SiO_2	8
Spodumene	$LiAl\ (Si_2O_6)$	3
Cassiterite	SnO_2	2
Topaz	$Al_2\ (SiO_4)\ (OH)_2$	2
Petalite	$LiAlSi_4O_{10}$	1

Acknowledgment:

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Physical beneficiation approach of Lithium and other metals from LIBs (Li-ion batteries) & PCBs (printed circuit boards) waste

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Keywords: Battery, Critical Raw Material (CRM), lithium, mineral processing, Printed Circuit Board (PCB).

Due to rising demand and the increased likelihood of supply bottlenecks, the availability of raw materials globally is experiencing increasing pressure. Global resource security is a growing concern, and access to Critical Raw Materials (CRM) has become a priority issue for governments around the world [1, 2]. The global demand for electronic devices resulted in a rise in the Waste of Electrical and Electronic Equipment (WEEE) to 53.6 million tons in 2019 [3]. More importantly, WEEE contains a large number of components that can have harmful effects on the environment and humans, and its indiscriminate handling and informal recycling can make WEEE a global public and environmental health problem [4]. Generally, Electrical and Electronic Equipment (EEE) contains many critical metals cobalt (Co), antimony (Sb), tungsten (W), etc., and platinum group metals (PGM), and near-critical elements such as tin (Sn), chromium (Cr), lithium (Li), and silver (Ag). They are essential components of EEE and have increasing importance in the transition to a green, low-carbon economy [5]. In addition, the European Union estimated that in 2030 the demand for metals and rare earth elements (REE) would be 3 times the actual one. So, it is thus clear the importance of the issues related to their possible recovery from end-of-life (EOL) products [6].

Particle ranges and chemical composition of batteries play a key role in determining how they can be recycled. Different techniques are required to extract and recover valuable materials. So, for the characterization of the black mass (BM), X-ray fluorescence (XRF) for the elemental compositions, X-ray diffraction (XRD) for crystal structure, Inductively Coupled Plasma (ICP) spectroscopy for chemical compositions, Scanning Electron Microscopy (SEM), and Energy Dispersive X-ray Spectroscopy (EDS) for mineralogical characterization and Laser-Induced Breakdown Spectroscopy (LIBS) for the elemental mapping and depth profiling of many materials were used.

Finally, based on the characterization results, beneficiation steps will be decided. In the case of black mass, it was expected the graphite particles would be easily separated from metal particles by density differences. So, sink-and-float and froth flotation (in hallimond tube) tests

were started. It is expected to separate metals by different techniques after the seperation of the graphite particles.

Particle size distribution analysis of the black mass revealed that 71.1% of particles are under 100 µm, and 28.9% are larger than 100 µm. Then samples under 53 µm were analyzed with a laser-PSD analyzer and it shows that 90% of them are under 27.16 µm and 10% are under 6.8 µm. This information is important for further separation and beneficiation steps since the separation of the fine and coarse particles needs different techniques.

Then, XRF analysis of the initial black mass shows there are 46.8% Mn, 17.9% Ni, 14.5% Cu, 6.6% Fe, and 5.6% Co (Table 1). In addition, XRF analysis of the different particle size ranges revealed that most of the Mn, Ni, and Co are on the particles less than 53 µm (Figure 1).

Table 1. XRF results of the initial black mass and different size ranges

	Black Mass size rangues (µm)					
	Initial	<53	53-100	100-200	200-500	>500
Mn	46.8	55.1	39.39	12.2	11.4	21.1
Ni	17.9	22.2	13.64	4.3	4.7	8.33
Fe	6.6	6.9	8.04	3.5	2.8	5.06
Co	5.6	7.1	4.26	1.2	1.3	2.44
P	2.9	2.5	2.86	2.2	2.6	2.95
Al	1.8	1.8	3.27	8.9	21.9	26.01
Cu	14.5	2.4	22.89	51.2	37.4	27.65
Mg	0.2	0.2	0.58	1.4	1.0	0.55
Sn	0.3	0.2	0.55	0.5	0.2	0.35
Cr	0.1	0.1	0.08	0.0	0.0	0.04
Ti	0.1	0.0	0.08	0.2	0.7	0.11
Pb	0.1	0.1	0.07	0.1	0.0	0.11
Zn	0.1	0.0	0.16	0.3	0.1	0.29

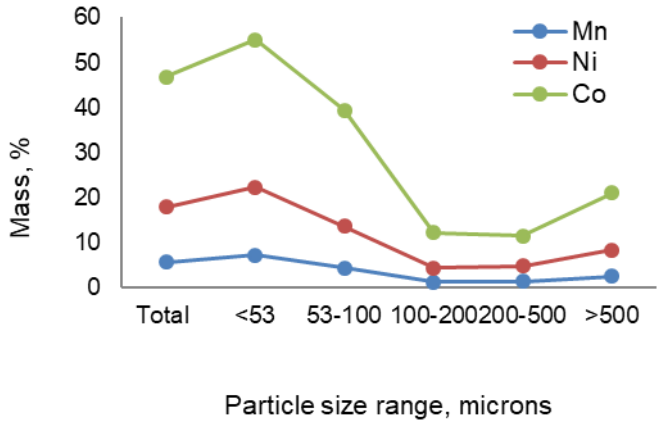

Figure 1. Mn, Ni, and Co distribution by particle sizes in the black mass.

Finally, SEM-EDS was carried out on black mass samples and the results revealed there are 2 types of particles: metals and graphite. Graphite particles are liberated but there are some metal particles on the surface of them. In the case of metal particles, there are liberated and agglomerated metals. For better visual understanding, SEM-EDS results were colored and named (Figure 2). More importantly, SEM-EDS results of the polished black mass show that the black particles are totally graphite and there are no metals inside them. In addition, metal particles are free of graphite and also there are liberated and agglomerated metal particles, which confirmed the initial data.

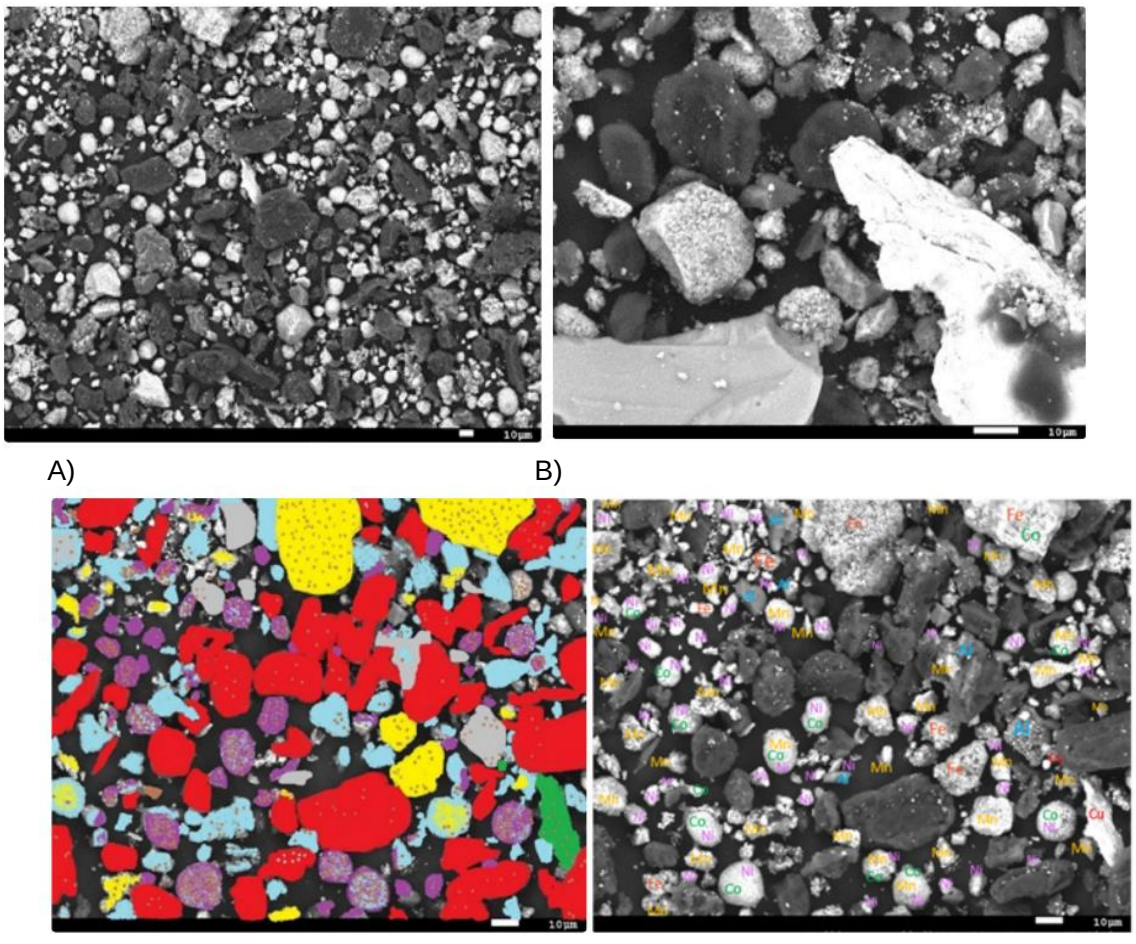

Figure 2. A) and B) are SEM-EDS images of the black mass; C) the colored SEM-EDS image of the black mass; D) named SEM-EDS image of the black mass.

For separating graphite from metal particles sink-and-float and froth flotation (in hallimond tube) tests have been done but the results were not as expected and the recovery of the metals in the floated and non-floted was more or less the same (Table 2). Some authors indicate the presence of the binder [7]. To solve the problem, it was decided to do pre-treatment to remove the binder and carry the tests, in order to desactivate the binder and finally try to separate graphite from metal particles.

Table 2. Black mass sink-and-float results.

				Float mass					No float mass				
N.	Sample	Mass, g	Density	g	%	Co, %	Ni, %	Mn, %	g	%	Co, %	Ni, %	Mn, %
1	BM	30	1.8	7.2	25	5.4	16.9	41.7	21.1	75	6.3	20.3	47.9
2	BM	504	1.8	103.8	21				401	79			
3	BM	405	1.8	123.1	27	4.4	13.6	38.2	332	73	4.8	14.8	43.3
4	BM	501	1.8	150.5	28				393	72			

Acknowledgment:

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Improvements in the sustainability of industrial hemp plantations by remote sensing and modelling of agro-biochemical parameters

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Keywords: industrial hemp, precision agriculture, remote sensing, UAVs, vegetation indices.

Recent technological advances allow **remote sensing (RS)** to be applied affordably to extensive crops, improving agriculture efficiency and sustainability [1]. In **precision agriculture**, **multispectral imaging (MI)** is used to apply preventive techniques based on vegetation indices, allowing the early detection of detrimental occurrences in the fields [2]. All in all, promoting more precise, sustainable, and economically efficient agriculture [3]. At the same time, **industrial hemp** is re-emerging as a novel product with innumerable applications, being the only cultivable natural fiber in Europe [4]. The high-added-value products obtained, as well as current low-tech agricultural practices, mean that now is the moment to apply **precision agriculture** to the hemp field.

The PhD herein proposes the modelling of agro-biochemical parameters of hemp plantations measurable by remote sensing. In particular, this dissertation focuses on the creation of predictive models for growth, productivity, and plague detection collected by an unmanned aerial vehicle (UAV). Using MI, **vegetation indices (VI)** are being generated and correlated to plants' health, chlorophyll amount, luxuriance, and volume [2]. At the same time, ground studies are being carried out in collaboration with other research centres, which enable the comparison of our UAV-generated indices with laboratory analysis results.

Applying the methodology exposed in Figure 1, two varieties (Uso 31 and Tiborszallasi), with two irrigation frequencies have been studied in a two-ha trial in Girona. From each of these four scenarios, four replications have been carried out, obtaining a total of sixteen parcels. Moreover, four additional parcels with a lower planting density function as a control (Figure 1 a.). Two drone flights were made with a DJI Phantom 3 equipped with a Parrot Sequoia camera. A total of 1003 and 974 pictures have been obtained respectively, in the Red, Green, Red-Edge and NIR bands in addition to RGB (Figure 1 b.1). The images have been post-processed using ODM for the creation of the orthophotos, Pix4D for calibration, creation of VI and volume calculations and QGIS for the analysis (Figure 1 c.1). The VI used for these preliminary results are NDVI and NDRE, selected for their suitability to plantation [5]. In parallel, the soil analyses were carried out bi-weekly with two measurements per parcel. Each sample was analysed *'in situ'*, measuring mass and height; and in the laboratory where percentages of hempseed and fibre before and after a drying process, and NIR spectroscopy were obtained (Figure 1 b.2 and c.2).

However, it is worth mentioning that the methodological proposal developed in the context of this study aims to be a generic solution where, regardless of the type of multispectral camera and platform chosen, multispectral measurements are compared with a physicochemical study conducted in the soil to validate the results for the creation of predictive agrochemical models.

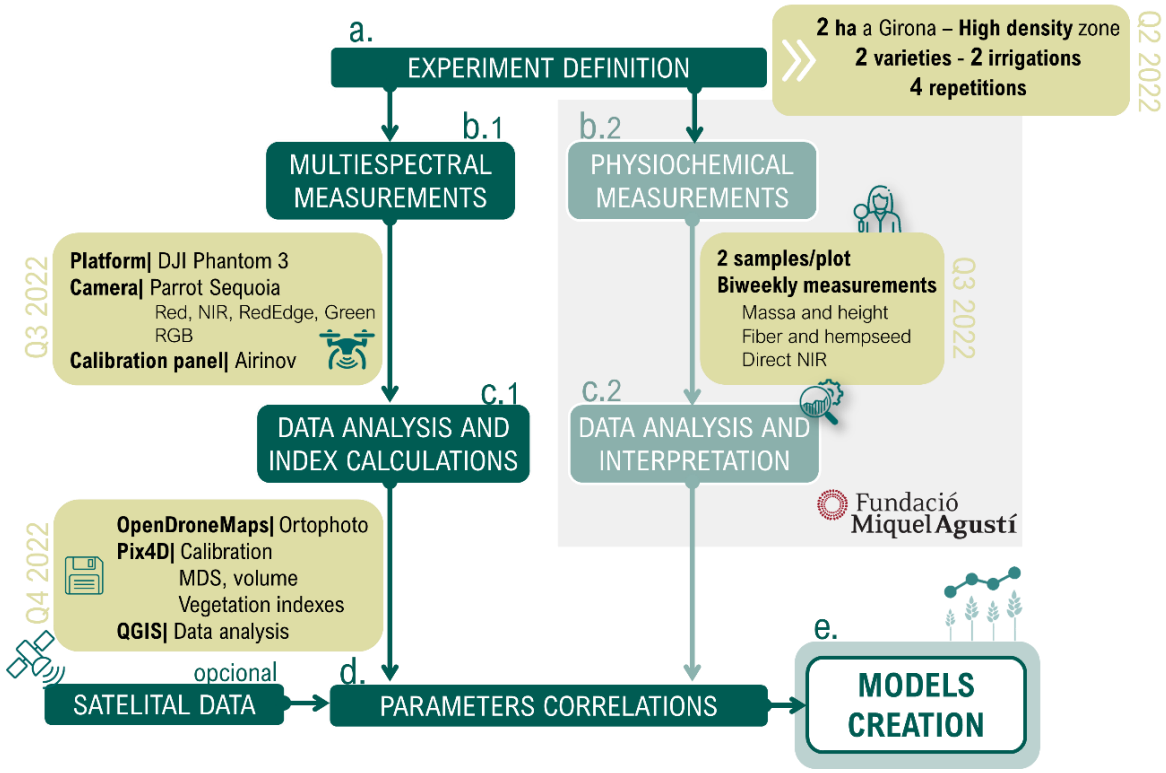

Figure 1: Methodology followed for the analysis of Uso31 hemp variety in Girona

The results analysed show a strong correlation between humidity, greenness indexes and plant productivity (Figure 1 d.). Such results suggest that it is possible to study a plantation via remote sensing, and through NDVI index calculation, estimate the total mass of wet or dry fibre that the crop is going to produce as can be seen in Figure 2.

Furthermore, significant linear correlations were found between the seeds' production the three stages of the seed during post-processing (harvested, screened, and industrially cleaned) and the NDVI indices measured before harvesting. These results unveil, for the first time, the possibility of estimating the final seed production from a hemp crop using the proposed remote sensing tool.

The results of the coefficient of determination (R^2) between 0.74 and 0.87 and Pearson (ρ), between 0.84 and 0.90, reveal a significant correlation between the NDVI value and the yield obtained. It is worth noting that the greatest values are found for fibre wet weight, being R^2=0.815 and ρ=0.903.

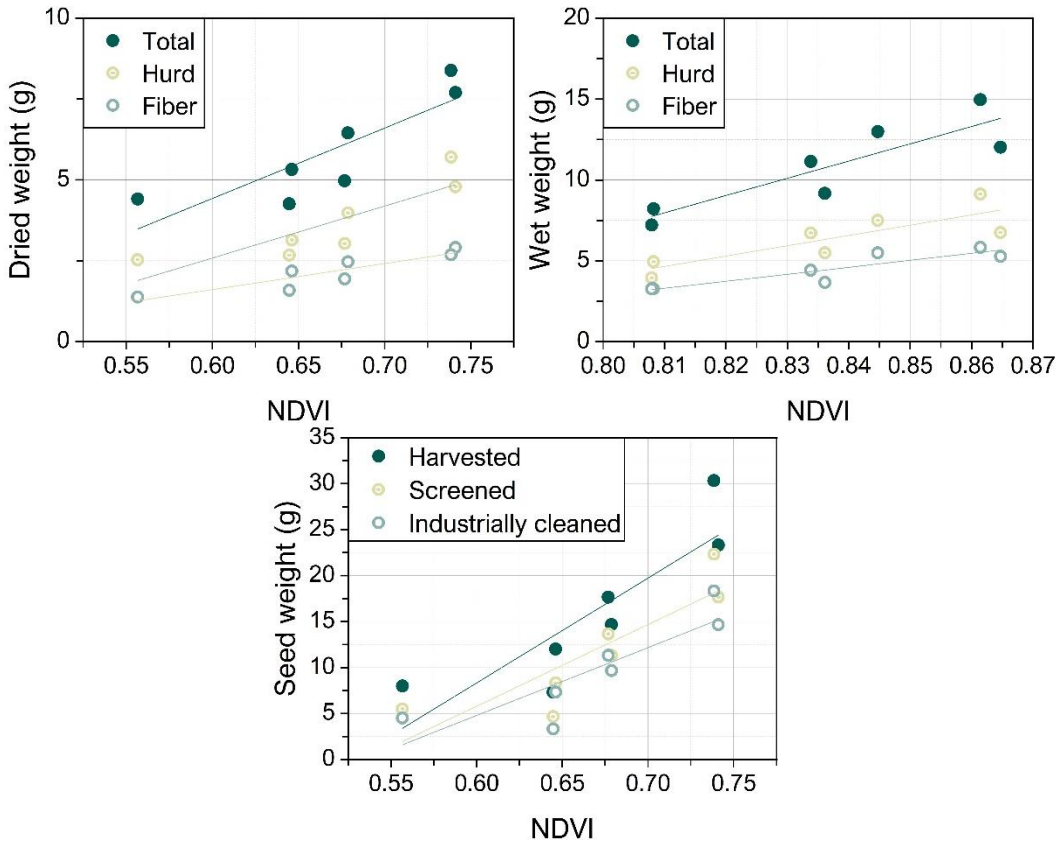

Figure 2: Linear correlations between NDVI indexes and the two main products of interest of a hemp crop, mass of fibre and mass of seeds.

Hence, the moisture levels in the areas with higher irrigation correspond to higher fibre yields. This pattern can be observed to all results from the second measurement similarly, but it has been presented in this graph as it provides the most visually informative representation. Nevertheless, it must be spotted that, independently of the irrigation level, the predictive capability of NDVI index remains intact since the accuracy of correlation with the total weight of the produced product (fibre/seeds) does not get affected. Likewise, two different plantation densities have been taken into account during this study, with zone 4 having a double planting density. Again, the NDVI index is able to assess the crop status independently of the planting density.

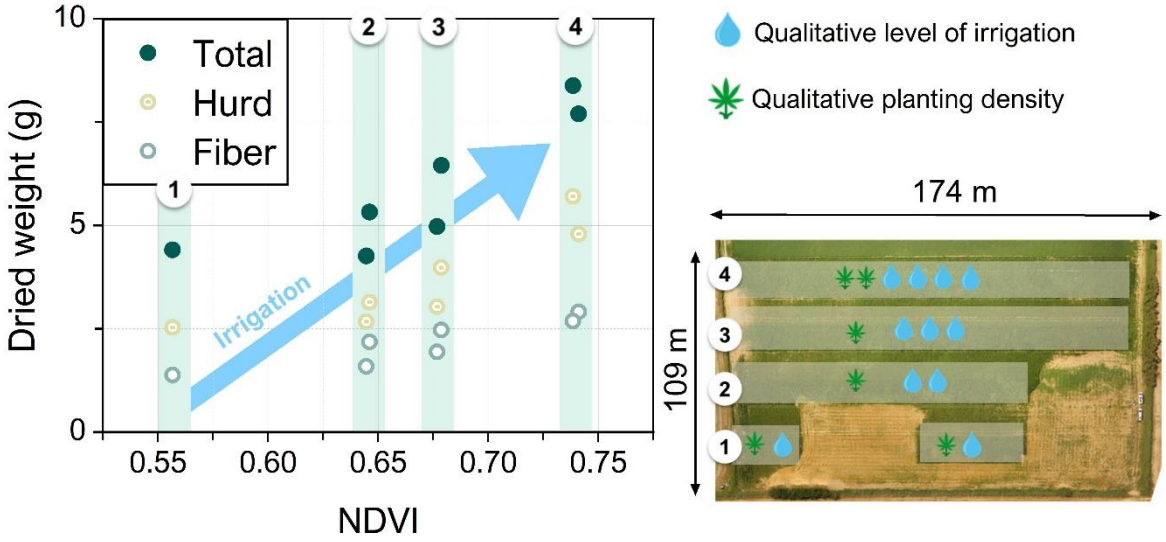

Figure 3: Linear correlations between NDVI index and total plant weight, hurd and fibre in relation with the qualitative humidity gradient and plantation density.

These calculations validate the thesis hypothesis; based on data from crops studied this year. Hence, the next natural step is to increase the crop fields as will be done this summer in collaboration with Centro Tecnológico Alimentario Nacional (CTAEX) studying 4 varieties in 6 ha of crops in Extremadura. In this way, more varieties, types of pruning, fertilisers used and planting densities, among other parameters, can be modelled.

This thesis will extend the EU's leadership in the development of local fibres and proteins and reduce its dependence on the external market, while reducing the pollution and losses generated in the transport of these products. In addition, it will contribute to strengthening the EU project **'Farm to fork", for a fair and environmentally friendly food system.**

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Design of 3D printed microfluidic systems to enable automated determination of important analytes during the extraction of crucial metals from e-waste

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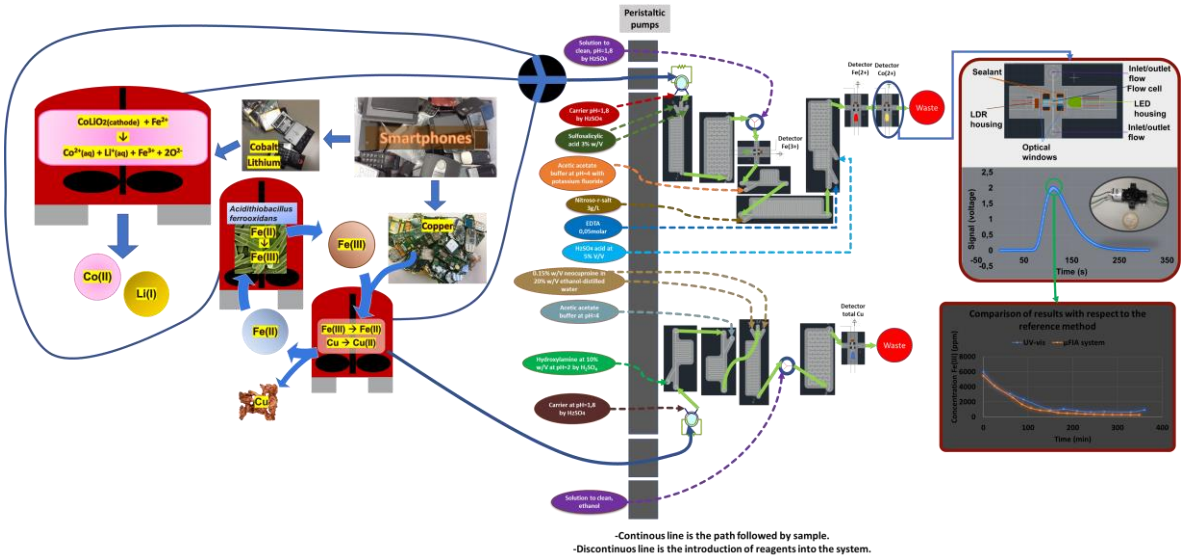
Keywords: bioleaching, e-waste, flow injection analysis (FIA), microfluidic, 3D-printed



The evolution of our way of life has been shaped by technological advancements. While these developments have been beneficial to humanity, they have also resulted in significant implications associated with the production of e-waste. Currently, a considerable amount of e-waste is produced annually, with this figure rising annually [1]. Some of this e-waste contains elements and compounds that are extremely toxic and hazardous, which can end up in the environment. Nevertheless, valuable metals such as cobalt, lithium, copper, silver, and gold are among the metals found in e-waste. These metals can be recovered using a variety of industrial techniques, including hydrometallurgy and pyrometallurgy. However, their economic viability is contingent upon the recycling of a significant quantity of waste. These procedures cannot be decentralized or conducted on a small scale. Furthermore, conventional methods are not environmentally sustainable and require a significant amount of energy (hydrometallurgy) or reagents (pyrometallurgy). Bioleaching is one of the more environmentally friendly small-scale recycling techniques that have been developed in the last ten years. In bioleaching, metals are

extracted from a solid matrix by via the actions of various microorganisms. The primary microorganism utilized in bioleaching is Acidithiobacillus ferrooxidans, a bacterium that consumes iron and utilizes oxygen as a final electron acceptor. This microbe has the capacity to convert Fe(II) to Fe(III), thereby acquiring the chemical energy necessary to convert CO2 into organic matter [2]. The bacterium produces Fe(III), which has the ability to oxidize insoluble metals in e-waste and convert them to soluble ions. In the case of this work, copper from PCBs was solubilized as Cu(II) and Co(III) from batteries was solubilized as Co(II).

In order to optimize the bioleaching process, it is essential to monitor key analytes, including Fe(II), Fe(III), Cu(II), and Co(II), in real time. This allows for the optimal operation of the process to be ensured. One of the most commonly used methods for the determination of these cations is the colorimetric method, which employs a chelating agent to form a colored complex that can be determined by UV-vis spectrophotometry. Phenanthroline is employed to determine Fe(II) and total iron, resulting in the formation of a colored red-orange complex [3]. Other chelating agents for Fe(III) include salicylic acid [4] and sulfosalicylic acid [5] which both produce a purple complex. For Cu(II), neocuproine generates an orange complex [6], while nitroso-r-salt (NRS) produces an orange complex with Co(II) [7], though NRS has low specificity for Co(II) [8]. All of these approaches have two significant limitations: their restricted linearity range, which is typically between 1 and 30 mg L-1; and their batch or discontinuous analysis, which necessitates the manual extraction of the sample from the bioreactor and consequently slows down the process. Due to the possibility of a maximum iron concentration in the reactor exceeding 6000 mg L-1, 3000 mg L-1 for Cu(II), and 4500 mg L-1 for Co(II), it is necessary to perform large sample dilutions. This could result in considerable analytical errors.

The objective of the current project is to develop a modular Flow Injection Analysis (FIA) system based on 3D-printed microfluidic platforms for the automated analysis of Fe(II), Fe(III), Cu(II), and Co(II). This system will enable the real-time monitoring of cation concentration, which will facilitate the identification and correction of operational deviations and enhance the understanding of the underlying processes. This method involves the injection of a volume of sample, which is pushed by a carrier, followed by conditioning or reaction of the sample. The sample is combined with the requisite reagents within the channels. Upon reaching the detector, the prepared sample produces a transient signal in the form of a peak. This signal will be used to make real-time, automatic determinations across a broad concentration range. Additionally, The other goal is to develop a new method that can specifically determine Co(II).

The most popular instrumental methods (potentiometry, voltammetry, UV-vis spectrophotometry, and fluorescence) have been searched for in a literature. The UV-vis method of measurement was chosen because it can be easily adapted to an FIA system as a flow-detector. Additionally, a comprehensive investigation was conducted to identify various approaches for enhancing the selectivity of the NRS for Co(II) [9,10]. While this is a viable option, it necessitates the utilization of all the aforementioned methods and the precise sequencing of the reagents [11,12]. Once this is accomplished, the procedure can be adapted for integration into a FIA system.

Finally, a FIA system which can determine Fe(III) in time it was done [13] and other for total copper [14]. A method for determine specifically Co(II) was found and is easily to adapt for FIA system to determine Fe(II) and Co(II) at the same time. The final goal is do a system which can determine Fe(II), Fe(III), Co(II) and Cu(II) at the same time in a broad range of concentrations, in time and in-situ.

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Ultrafine particles characterization from different transport sources

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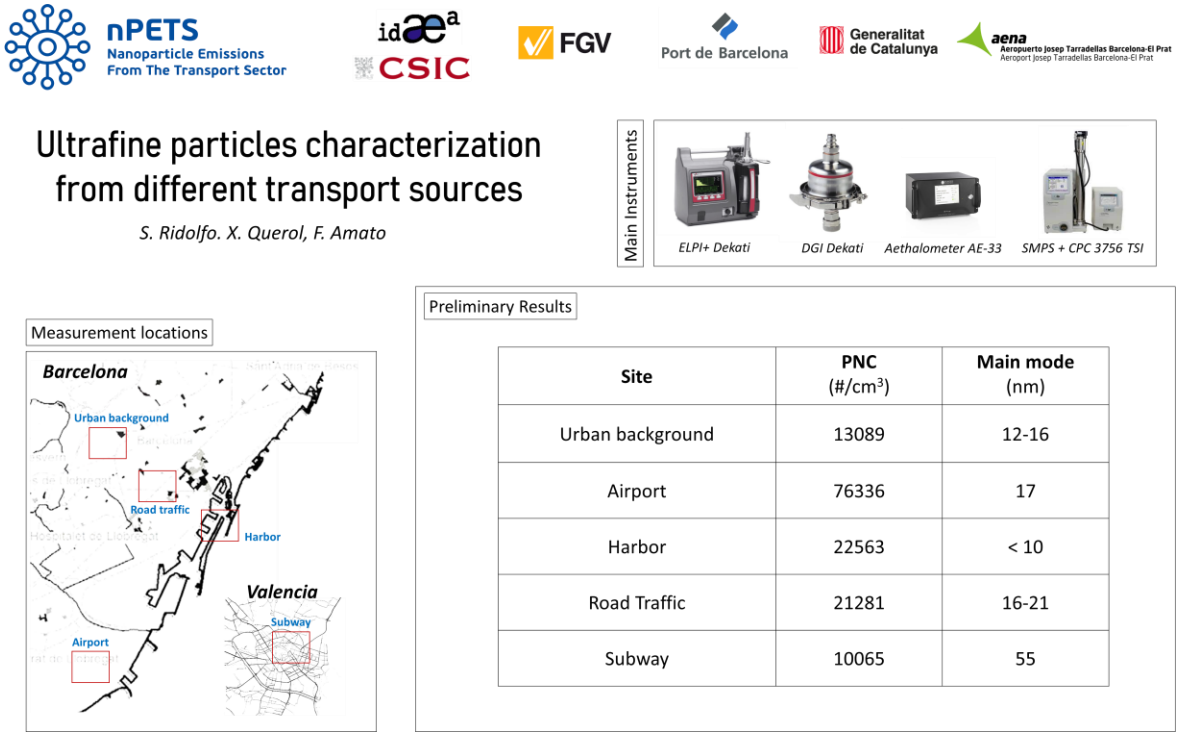
Keywords: airport, harbor, nanoparticles, road traffic, source apportionment, subway

Graphical Abstract



Ambient air ultrafine particles (UFP; particles with a diameter <100 nm) are of increasing concern according to WHO air quality guidelines and the European legislation (WHO, 2021). Due to the lack of sufficient epidemiological evidence for the independent adverse effects of UFP, the World Health Organization (WHO) recommended good practices rather than specific guidelines (WHO, 2021). These practices include quantifying UFP in terms of particle number concentration (PNC) and integrating UFP monitoring into existing air quality systems. Responding to these recommendations, the new European Air Quality Directive draft (EC, 2023) includes

requirements to monitor UFP concentrations and PNSD in urban supersites, rural areas, and pollution hotspots, including traffic, harbors and airports, among others.

The nPETS (Nanoparticle Emissions from The Transport Sector: https://www.npets- project.eu/) is a H2020 project that aims to monitor and sample UFP emitted from various transport modes in four European cities (Barcelona, Stockholm, Milan and Thessaloniki). In the framework of the nPETS project, UFP monitoring and sampling in Spain included five different monitoring sites (urban background, traffic site, airport and harbor in Barcelona, and subway in Valencia). Two measurement campaigns (warm and cold seasons) with the same methodology were carried out at each site with a mobile laboratory van, each lasting one month. The deployed instrumentation included ELPI+ and DGIs impactors, coupled to CPC/SMPS/EEPS for particle number size distribution (PNSD) and sampling, high volume PM_1 and PM_{10} samplers, aethalometers, and gaseous pollutant analyzers. Sampled filters underwent inorganic and organic chemical speciation (by means of ICP-AES, ICP-MS and GC-MS), animal and human toxicology tests, as well as microscopic (SEM and TEM) analysis. PMF multivariate analysis method (Rivas, 2020) was performed for source apportionment using PNSD data > 10 nm.

Higher 24-hour average PNC were found at the airport of Barcelona (76197 pp/cm^3 and 73475 pp/cm^3, for warm and cold seasons respectively). The road traffic site showed higher PNC during the cold season compared to the warm season (26000 pp/cm^3 vs 16562 pp/cm^3), while at the harbor PNC were higher during the warm season rather than the cold one (25282 pp/cm^3 vs 19843 pp/cm^3). No seasonal differences were found at the urban background (UB) location (warm: 12933 pp/cm^3; cold: 13244 pp/cm^3). The measurements within the Valencia metro were carried out only during one month, without distinction between the cold and warm season, and an average PNC of 10065 pp/cm^3 was observed.

PNSD was unimodal at almost all sites, with a peak between 12 and 16 nm at the UB, between 16 and 21 nm at the road traffic site, at 17 nm at the airport, and < 10 nm at the harbor. The subway of Valencia was the only site reporting a bimodal size distribution with a first peak <10 nm and a second peak at 55 nm.

Source apportionment identified six different sources of nanoparticles at the airport site: Taxiing, Takeoff, Photonucleation, Industrial/Shipping, Diesel, Regional/Biomass burning. Chemical analysis of quasi-UFP collected on ELPI+ filters (from 2 to 6) revealed higher concentrations (> 2-fold) of Fe, Al, Cr, Cu, Mo, Mn, Pb, Ti and Sb at the airport compared to the UB, with Al exhibiting the most pronounced disparity.

Acknowledgment:
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Optimization of liberation and energy consumption in the processing of Sn-Zn ores from the Central Andean Belt by means of pretreatment with high pressure rollers

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Keywords: milling, energy efficiency, liberation, optimization, Bolivia.

Graphical Abstract

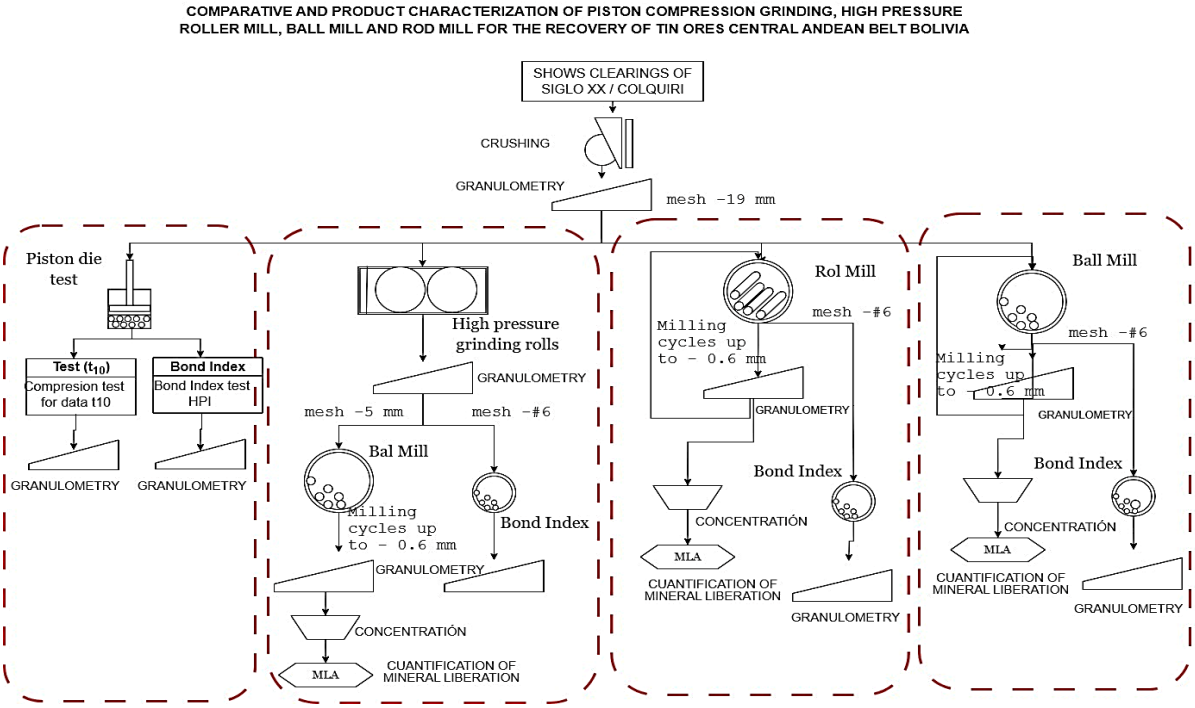

Figure 1. Diagram of experimental processes for Sn and Zn recovery proposed in the study.

1. Itroduction

Bolivia has been a mining country with exploitation of silver and tin ores predominantly [1]. Mining in this country has usually been applied inefficiently and it has resulted in high levels of environmental pollution [2], [3], [4]. However, many of these residues have become a resource and they can still be processed, with the advantage that they have already been comminuted, and therefore the crushing energy is not necessary. This is the case of the tin deposits in the waste dumps in the town of Siglo XX, municipality of Llallagua, department of Potosí, which make up an area of approximately 360.000 m^2. The material consists in an old waste piles, formed with

pebbles of sizes from 20 mm to 50 mm, It is estimated that there may be around 17 million tons of this material [5]. Another interesting deposit in this regard is one called Colquiri mine, located in the department of La Paz, which has streaks of Sn and Zn minerals with an approximate reserve of 2.7 million tons; this deposit is currently being exploited, although with traditional techniques and little optimization of mineral and energy resources.

According to Dold [6], mining must be carried out in a sustainable manner, which implies maximizing the use and minimizing the waste produced. Under this premise, the aim is to establish a procedure for the concentration of Sn and Zn minerals from the Central Andean Belt that optimizes the liberation of the ore while reducing the energy consumption of the process.

The new cutting-edge technology in the optimization of grinding processes is HPGR (High Pressure Grinding Rolls). The selective cracking generated by high pressure roller mills is highlighted, as reported in some studies on copper ores [7] and [8] and gold ores [9]. Such selective cracking increases the degree of ore recovery, for example, the application of these methods for tin ores reports higher ore recovery when using high pressure mills [10]. Hamid [11] compares the recovery of Ta and Sn ores using ball mills or mixed grinding with high pressure roller mills followed by ball mills and shows a clear increase in the latter case.

2. Materials and Methods

The material coming from the Siglo XX deposits are plebbes from a previous process, as can be seen in figure 2. The material coming from the Colquiri mine are rock pieces from 50 mm to 200 mm taken from the main feed belt of the plant, which in turn come from the interior of the mine.

Figure 2. A) View of the Siglo XX waste dump, B) a reference of the pebbles size under study.

To take a base study size, from which the energy used in size reduction can be quantified, samples from both deposits are reduced to a size of -19 mm (#3/4 in mesh) in a 490 mm diameter ball mill, a material weight of 10.5 kg and registering an amperage of 5.2A with a three-phase motor (Figure 1). From there, particle distribution plots (Figure 2) will be obtained for input to the subsequent comminution processes.

By performing controlled comminution processes, recording material weight, residence time in the mill, current consumed, particle size reduction ratio can be obtained and related to energy consumption. Therefore, ore concentration will be performed to quantify the ore recovery with the different grinding methods. Finally, the energy cost of particle size reduction will be correlated with the amount of valuable mineral liberation obtained, seeking to obtain a predictive model that combines these variables.

In addition, grinding energy quantification (Bond Index) will be performed in a standard Bond mill and by means of piston compression tests for the Bond Index of high-pressure roller mills.

To characterize the materials under study, chemical content will be determined by X-ray fluorescence (XRF). Mineralogical characterization of the samples will be performed by X-ray powder diffraction (XRD). Texture and other mineral features will be checked by, optical microscopy, electron microscopy and electron microprobe. In order to modelize liberation, quantitative automatic mineralogy analyzer will be performed.

3. RESULTS

The feed particle size distribution of both Colquiri and Llallagua deposits (Figure 3), present small differences in their distribution. However, the main parameters, such as D80 and top-size, are of the same order of magnitude. Fine material is considered below 600 microns, and in both cases, it is non-existent. On the other hand, the particle size distribution for the Llallagua samples, feed (serie 1) and product (serie 2) after a grinding process of 2 minutes (Figure 4), the reduction ratio is about 7:5. This result is according with the short residence time. Fines phases is also increased trough the experimental curve. The experimental power registered in this process was 2.09 kW with a energy by mass used of 6.34 kW*hr/ton.

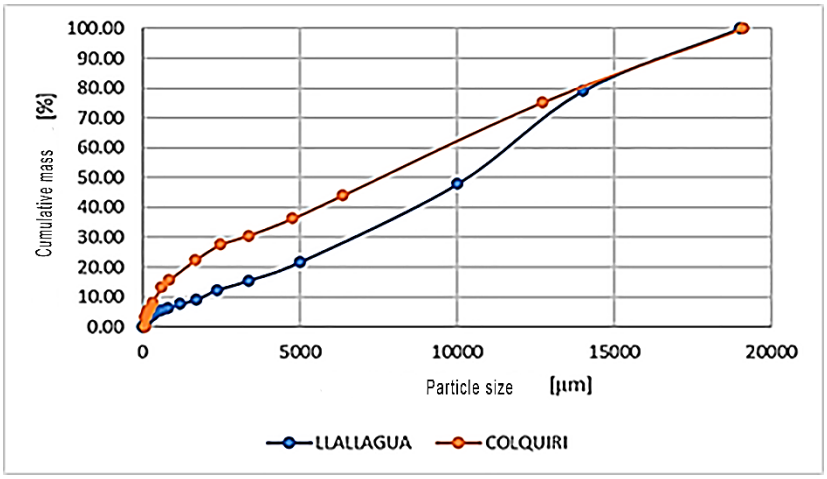

Figure 3. Process input particle size distribution, Llallagua and Colquiri mine deposits.

In addition, grinding energy quantification (Bond Index) will be performed in a standard Bond mill and by means of piston compression tests for the Bond Index of high-pressure roller mills.

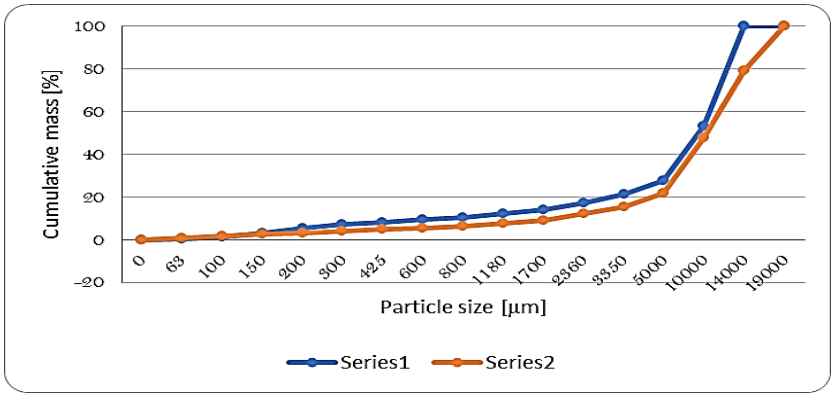

Figure 4. Particle size distribution at process input and after first milling, Llallagua field.

To determine the release parameters, chemical characterization will be performed by X-ray fluorescence (XRF). Mineralogical characterization of the samples will be performed by X-ray powder diffraction (XRD), optical microscopy, electron microscopy and electron microprobe. Quantitative mineralogy will be performed by Rietveld refinement using HighScore Plus software.

4. Acknowledgment

Great grateful for the support of the Manresa School of Mines of the Polytechnic University of Catalonia for the usage of the Mining Laboratory. The effort made by the CCD (Centre de cooperació per al desenvolupament) is also appreciated. To the Metallurgical Engineering Department of the Polytechnic University of Oruro, for the use of its facilities, as the Mineral Concentration Laboratory and to the Colquiri Mining Company for their support in providing ore samples for this study.

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Three-dimensional pore morphology study of atomised aluminium alloy powder

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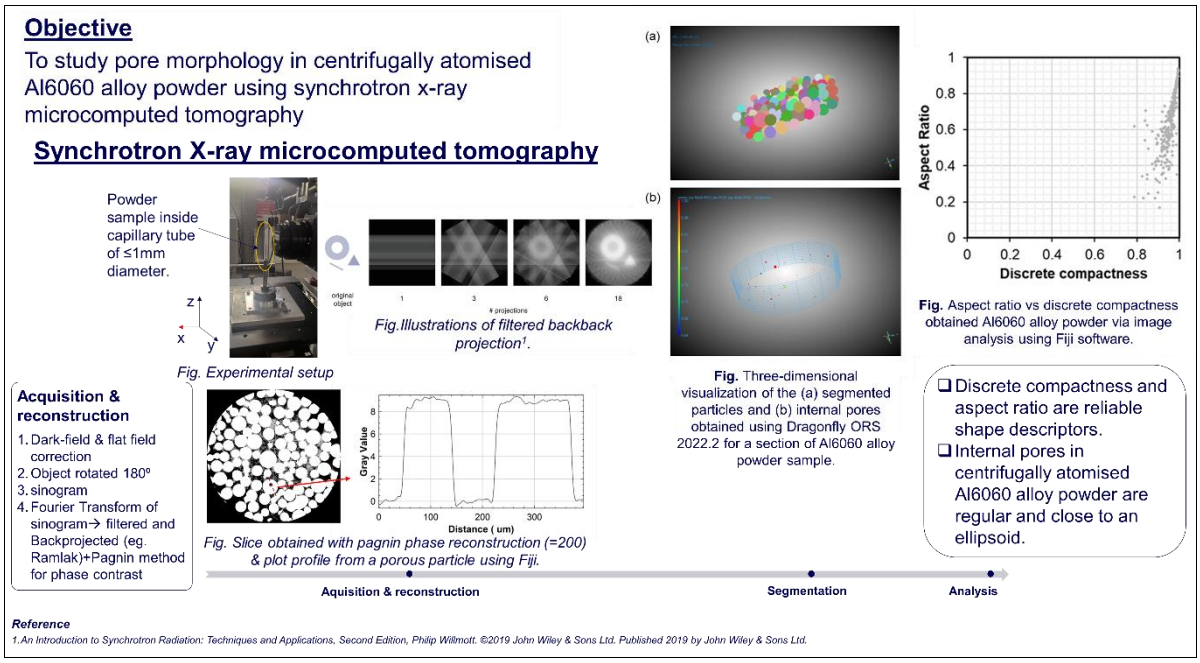
Keywords: Internal porosity, Centrifugal atomisation, Synchrotron X-ray microcomputed tomography



Internal porosity is a critical issue regarding the feedstock quality in metal additive manufacturing (AM). Irregular pore formation can be associated with insufficient molten material to compensate for shrinkage during the cooling stage during atomisation [1], [2]. Spherical pores are generally associated with gas entrapment [3] during atomisation. Problematically, the feedstock's gas porosity leads to the AM part's porosity. Studies have mainly focused on additive manufacturing process parameters, like optimising scanning strategy, to reduce the cracks and pore formation in the printed part. However, it is complex to reduce gas pores with this approach if it is influenced by the feedstock production route.

This study uses Al6060 alloy powder, produced via centrifugal atomisation sieved to less than 150µm. The characterisation was performed by synchrotron x-ray micro-computed tomography to understand the three-dimensional pore morphology. This is a powerful non-destructive imaging technique, to obtain high-resolution visualisation of internal features. Image analysis is performed on the reconstructed data (image stack). The results suggest the presence of internal pores. Qualitative estimation for the entire Al6060 powder sample is performed using Fiji to reduce computational demand. Figure 1 suggests that the pores are spherical with sphericity close to 1. The sphericity is calculated using the surface area of the region of interest (ROI) and is influenced by the noise in the data.

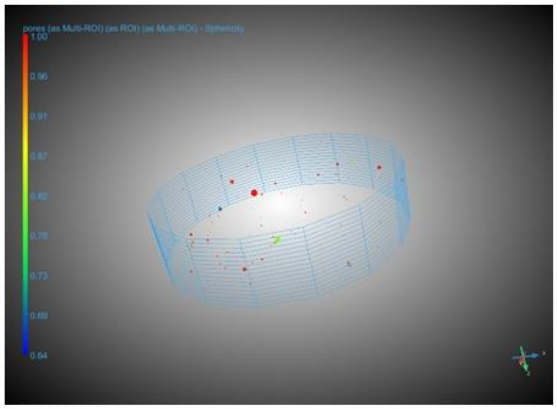


Figure 1. Three-dimensional visualization of the internal pores obtained using Dragonfly ORS 2022.2 for a section of Al6060 alloy powder sample.

Parameters like discrete compactness and aspect ratio are used in this study as shape descriptors. Discrete compactness measures the proximity of the ROI to a regular geometry and is more accurate as it is not influenced by the voxel shape. As the value approaches unity, it signifies that the ROI is regular. The aspect ratio is the ratio between the ROI's minimum and maximum capillary distance. For a perfect sphere, the aspect ratio is equal to unity. When the value approaches zero, the region of interest is elongated.

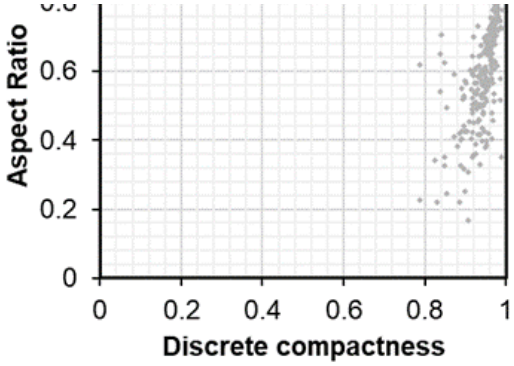


Figure 2. Aspect ratio vs discrete compactness obtained Al6060 alloy powder via image analysis using Fiji software.

Figure 2 shows the results from the quantitative estimation using Fiji. Most of the pores have a discrete compactness greater than 0.8, and the aspect ratio ranges from 0.4 to 0.9, suggesting the pore morphology is regular and close to an ellipsoid.

It can be concluded that discrete compactness is a reliable shape descriptor compared to sphericity to determine if the pore morphology is regular. Additionally, the aspect ratio seems to be a robust determiner of whether the pores are elongated. The internal porosity in the analysed Al6060 powder sample exhibits a regular morphology resembling an ellipsoid. The insights from this analysis can be used to optimise the atomisation parameters to limit the porosity in the produced aluminium alloy powder.

Acknowledgements

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eBC mass concentration in urban Europe

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Keywords: Air quality, Equivalent black carbon, Filter absorption photometer, Mass absorption cross-section, Source apportionment

Equivalent Black Carbon (eBC) has become one of the key targets for current research on air quality (AQ). To incorporate eBC as a new variable in AQ guidelines and to develop effective mitigation strategies, it is crucial to estimate its mass concentration in a consistent way throughout the AQ monitoring networks (AQMNs) with minimal uncertainties. Accordingly, the variability of eBC mass concentrations and their sources in urban Europe were analyzed to provide insights into the use of eBC as an advanced AQ parameter for AQ standards. In the framework of RI-URBANS project (EC, H2020), eBC mass concentration datasets were compiled covering the period between 2006 and 2022 from 50 measurement stations, including 23 urban background (UB), 18 traffic (TR), 7 suburban (SUB), and 2 regional background (RB) sites. eBC mass concentrations were derived from filter absorption photometers (FAPs), mainly Aethalometers and MAAPs. The results highlighted the need for the harmonization of eBC measurements to allow for direct comparisons across urban Europe. Here we summarized the results of spatial and temporal variations of eBC and present recommendations for harmonizing its measurements.

Phenomenology: The eBC mass concentrations showed a decreasing trend as follows: TR > UB > SUB > RB (Fig. 1). Furthermore, a clear decreasing trend was observed in the UB sites moving from Southern to Northern Europe. The eBC exhibited significant spatiotemporal heterogeneity, including marked differences and variable contributions of pollution sources to bulk eBC between different cities. Seasonal patterns in eBC were also evident, with higher winter concentrations observed in a large proportion of cities, especially at UB and SUB sites. The contribution of eBC from liquid fuel combustion, mostly traffic (eBCLF) was higher than that of solid sources, mostly biomass burning (eBCSF) in all European sites studied. Nevertheless, eBCSF still had a substantial contribution to total eBC at a majority of the sites. eBC trend analysis revealed decreasing trends for eBCLF over the last decade, while eBCSF remained relatively constant or even increased slightly in some cities (Savadkoohi et al., 2023).

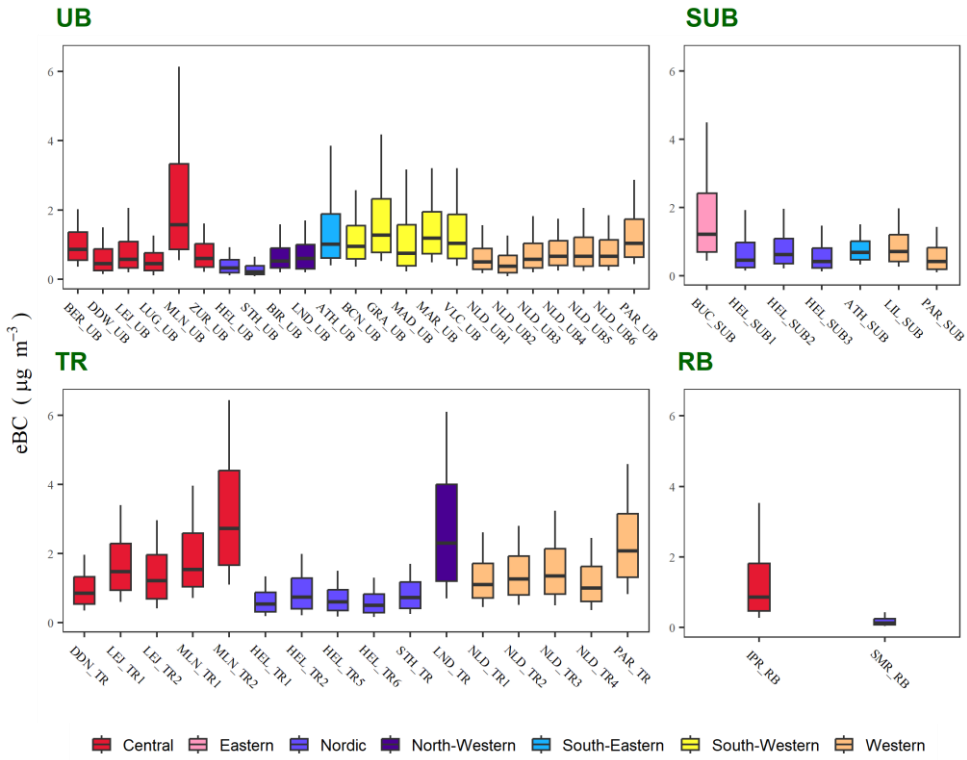

Figure 1. Variability of hourly averaged eBC mass concentrations at 50 sites between 2017 and 2019 categorized by the type of site and region from Savadkoohi et al. (2023).

Recommendations: In order to obtain a reliable determination of eBC mass concentrations derived from FAPs measurements, the mass absorption cross-section (MAC) for converting the absorption coefficient (babs) to eBC should be quantified appropriately. The spatial–temporal variability of the MAC obtained from simultaneous elemental carbon (EC) and babs measurements performed at 22 sites were studied. Different methodologies for retrieving eBC integrating different options for calculating MAC were investigated including: locally derived, median value calculated from 22 sites, and site-specific rolling regression MAC. The eBC concentrations that underwent correction using these methods were identified as LeBC (local MAC), MeBC (median MAC), and ReBC (Rolling MAC) respectively. Pronounced differences (up to more than 50%) were observed between eBC as directly provided by FAPs (NeBC; Nominal instrumental MAC) and ReBC due to the differences observed between the experimental and nominal MAC values. The median MAC was 7.8 ± 3.4 m2/g from 12 Aethalometers at 880 nm, and 10.6 ± 4.7 m2/g from 10 MAAPs at 637 nm (Fig. 2).

The experimental MAC showed significant site and seasonal dependencies, with heterogeneous patterns between summer and winter in different regions. Long-term trend analysis of eBC, revealed that the trend may be clearly affected by the way eBC is calculated due to the variability of MAC. Thus, NeBC and EC decreasing trends were consistent at sites with no significant trend in experimental MAC. Conversely, where MAC showed statistically significant trend, the NeBC and EC trends were not consistent while ReBC concentration followed the same pattern as EC. These results underscore the importance of accounting for MAC variations when deriving eBC

measurements from FAPs and emphasizes the necessity of incorporating EC observations to constrain the uncertainty associated with eBC. RI-URBANS recommends the use of co-located measurements of babs and EC mass concentrations by expanding monitoring networks to include regular EC sampling and periodically using EC measurements to obtain rolling MAC. However, whenever EC observations are unavailable, we recommend applying the median MAC value of 10.6 m2/g obtained in this work when babs is provided by MAAP at 637 nm and the MAC value of 7.8 m2/g when harmonized babs is provided by Aethalometers at 880 nm (Savadkoohi et al., 2024).

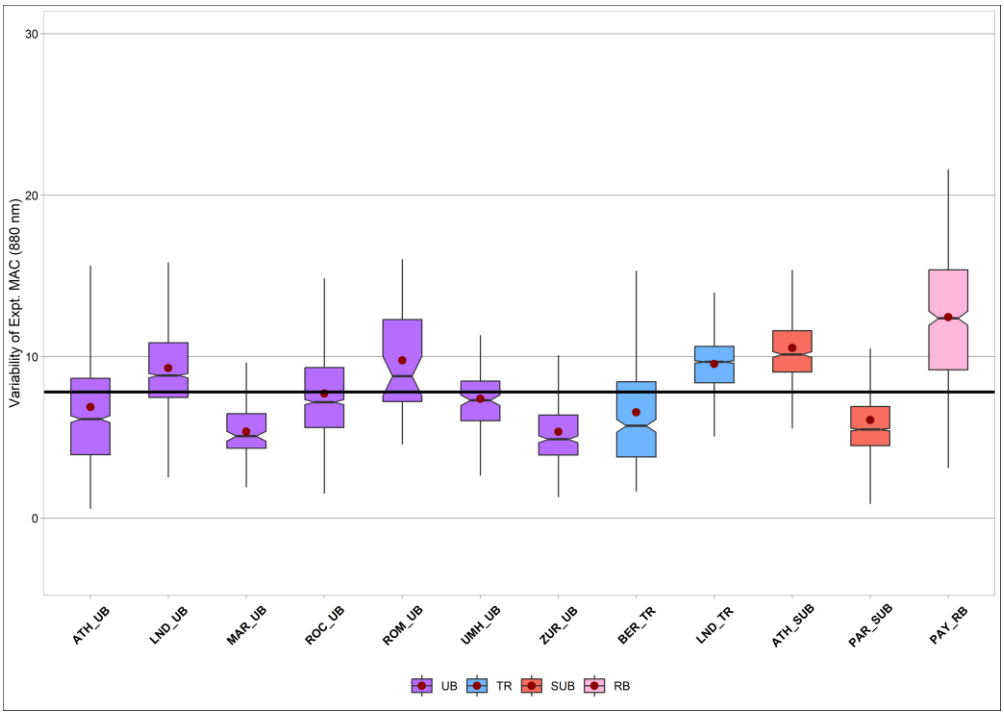

Figure 2. Variation in experimental MAC at instrument-specific wavelengths (AEs: 880 nm), grouped by site type (urban background [UB], suburban background [SUB], traffic [TR], and regional background [RB]). The solid black line denotes the total experimental median MAC for 12 AEs at 880 nm (7.8 ± 3.4 $m^2\ g^{-1}$) from Savadkoohi et al. (2024).

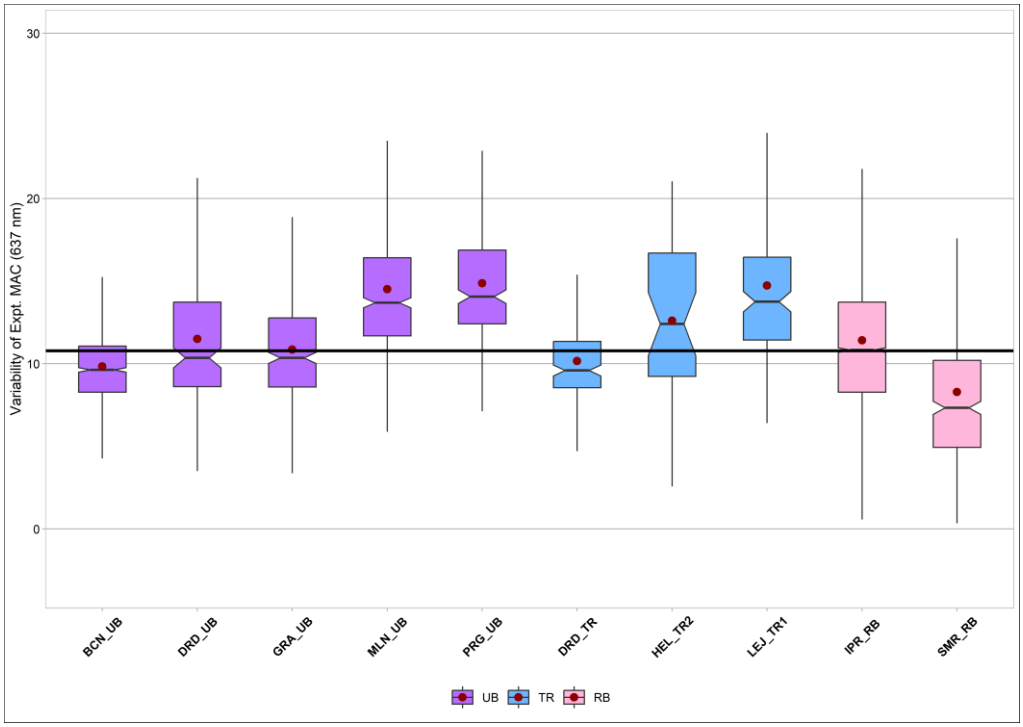

Figure 2. Continued. Variation in experimental MAC at instrument-specific wavelengths (MAAP: 637 nm), grouped by site type (urban background [UB], suburban background [SUB], traffic [TR], and regional background [RB]). The solid black line denotes the total experimental median MAC for 10 MAAPs at 637 nm (10.6 ± 4.7 $m^2 g^{-1}$) from Savadkoohi et al. (2024).

Acknowledgment

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A proposal for a new method to assess road traffic noise in the United Kingdom

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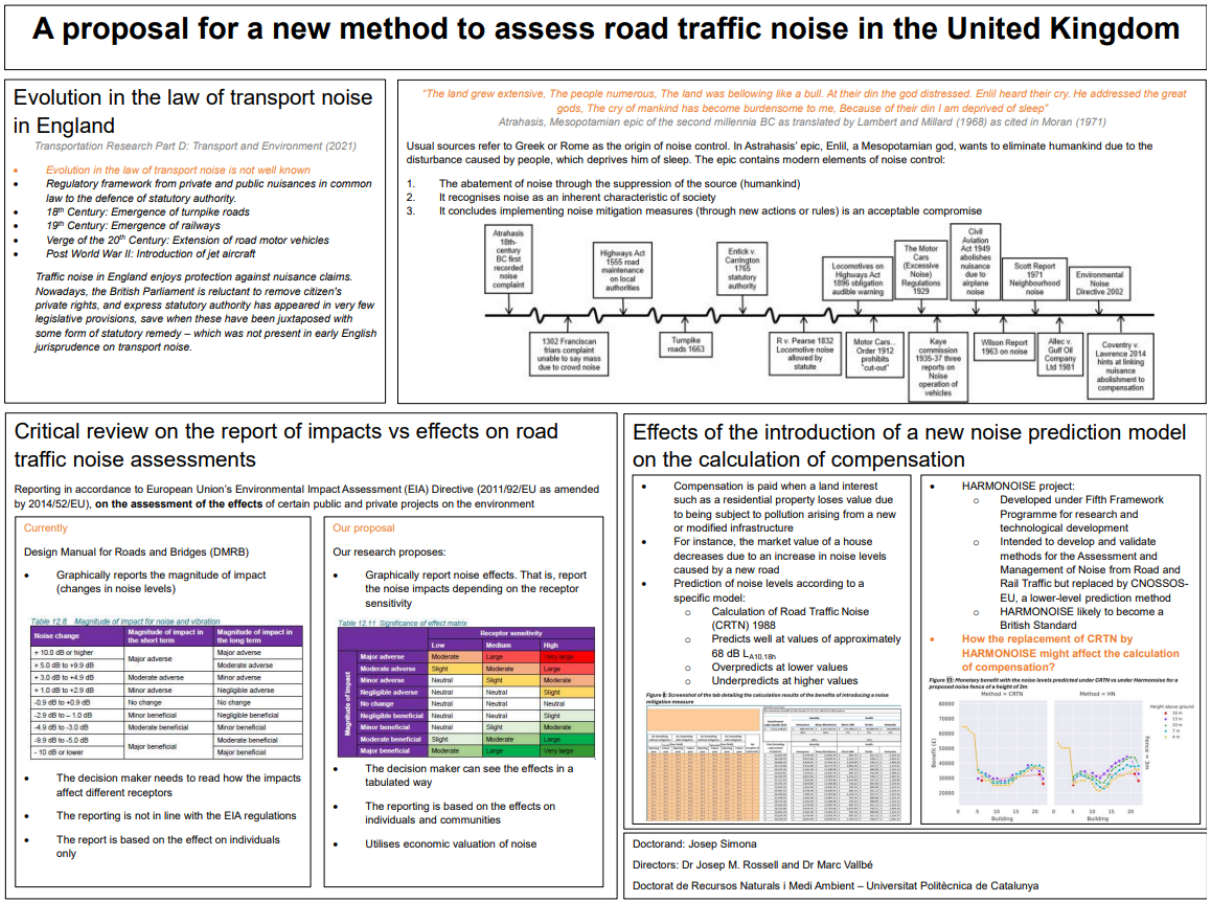
Keywords: compensation, law, Harmonoise, noise, transport.

Graphical Abstract



Introduction

Road traffic noise is the most common source of noise nuisance in the United Kingdom (UK). As such, it is frequently necessary to implement mitigation measures to reduce this road traffic noise, often in the form of noise barriers or fences. The introduction of noise barriers must be justified on a case-by-case basis.

The decision-making process regarding the introduction of a noise barrier can involve several parties. The acoustic consultant may aim to minimise the noise levels at the nearest sensitive receptors. The landscape architect might strive to minimise the visual impact of the barrier,

ensuring it is not excessively high. The project manager might want to ensure that no unnecessary expenditure is incurred.

Residents' priorities can also vary. Some might prioritise noise reduction, while others might prioritise preserving open views. Thus, a balanced and considered approach is required when deciding on the introduction and design of noise barriers.

Before a mitigation measure is introduced, a model is produced to predict its results. Thus, a noise fence can be modelled considering different heights, positions, layouts, etc., and a decision must be taken on which of the modelled scenarios to implement, if any.

The current noise prediction model in the UK is the Calculation of Road Traffic Noise (CRTN), originally published in 1975 and amended in 1988. Harmonoise, developed in the early 2000s and partly based on the Nord2000 method, was intended to be used as the common European method for the production of strategic noise mapping. However, the current CNOSSOS-EU method was ultimately based predominantly on other methods. The British Standards Institution plans to adapt Harmonoise to a British Standard.

Our research investigates the factors that must be considered in any proposal that contemplates replacing CRTN with a new method grounded in Harmonoise. It specifically focuses on the decision-making process regarding the suitability of introducing a noise fence at a particular location. This approach will facilitate the design of test cases to ascertain the potential implications of implementing a new, specific road traffic noise model.

Effects of the introduction of a new noise prediction model on the calculation of compensation

Our research focuses on the consequences of replacing CRTN with HARMONOISE in terms of compensation paid for the loss of value of an interest of land under the Land Compensation Act 1973. For instance, the loss of market value of a residential property subject to higher noise levels after the construction of a new road. Before responding this question, we have found necessary to respond two previous questions. Firstly, what were the precedents to the current regulation of noise in England. That is, how did we arrive to the current situation. Secondly, how are the noise effects of new roads assessed in England. The research has resulted in the proposal of a new method for the assessment of road traffic noise in the United Kingdom.

Evolution in the law of transport noise in England

In 2021, we published the article Evolution in the law of transport noise in England [3]. The article tracked the evolution of the regulatory framework in relation to transport noise in England from private and public nuisances in common law to the defence of statutory authority. The article looked at the evolution of transport noise law focusing primarily on the emergence of turnpike roads in the eighteenth century, railways in the nineteenth century, the extension of road motor vehicles in the verge of the twentieth century and, lastly, the introduction of jet aircraft after World War II. The introduction of these noise sources shaped the current noise regulatory framework in England. Traffic noise in England enjoys protection against nuisance claims. Nowadays, the

British Parliament is reluctant to remove citizen's private rights, and express statutory authority has appeared in very few legislative provisions, save when these have been juxtaposed with some form of statutory remedy – which was not present in early English jurisprudence on transport noise.

The paper also included a reference to Atrahasis [4], a Mesopotamian epic of the second millennia BC, which is not commonly mentioned as the potential first reference to a noise complaint. In Astrahasis' epic, Enlil, a Mesopotamian god, wants to eliminate humankind due to the disturbance caused by people, which deprives him of sleep. The epic contains modern elements of noise control. First, with the abatement of noise through the suppression of the source (humankind), later recognising noise as an inherent characteristic of society, and finally, agreeing that implementing noise mitigation measures (through new actions or rules) may be an acceptable compromise.

A proposal for a new method to assess road traffic noise in the UK

The UK's Design Manual for Roads and Bridges (DMRB) LA 111, published in 2019, contains the core methodology for the assessment of noise effects arising from road schemes. Our research has identified some weaknesses in the current methodology in DMRB LA 111. We have proposed a new reporting methodology of operational noise effects to make the outputs of the assessment clearer in terms of requirements of the environmental regulations and of the requirements of the planning regulations. Our proposal considers not reporting the effects on individual receptors but also the effects on communities, include cost-benefit analysis methods as part of the assessment and report the findings in the form of a table that would facilitate the role of the decision taker on either approving a road project or agreeing in introducing a noise mitigation measure such as a noise barrier.

Factors to consider on the decision of introducing a noise mitigation measure

Over the past two decades, cost-benefit analysis methods have been introduced for the valuation of environmental impacts. In the context of noise, the Department for Environment, Food and Rural Affairs has published values for the economic impact of various noise effects. This has enabled the conversion of noise levels into monetary values, based on their impact on humans. The subsequent step involved using cost-benefit analysis to determine whether a potential new mitigation measure delivered value for money.

As part of the research project, we have modelled several scenarios to discuss whether the introduction of a noise mitigation measure, such as a noise fence, is appropriate. The scenarios have been modelled under CRTN and Harmonoise and their results compared. We have found differences in the predicted results, which have downstream consequences that need to be considered. In England, these consequences might manifest in the form of compensation paid under the Land Compensation Act 1973, and the outcome of the cost-benefit analysis, which in turn influences the decision on whether to introduce noise mitigation measures.

We have sought to determine whether the current methodology, which assumes that "environmental" effects encompass "devaluation" effects, is accurate, or whether these effects should be accounted for separately, that is, both added as costs. Our proposal is that, unlike with

the current methodology, land or property devaluation should be considered in addition to the monetary valuation of environmental effects.

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Strategies for Sustainable Extraction in Surface Mining

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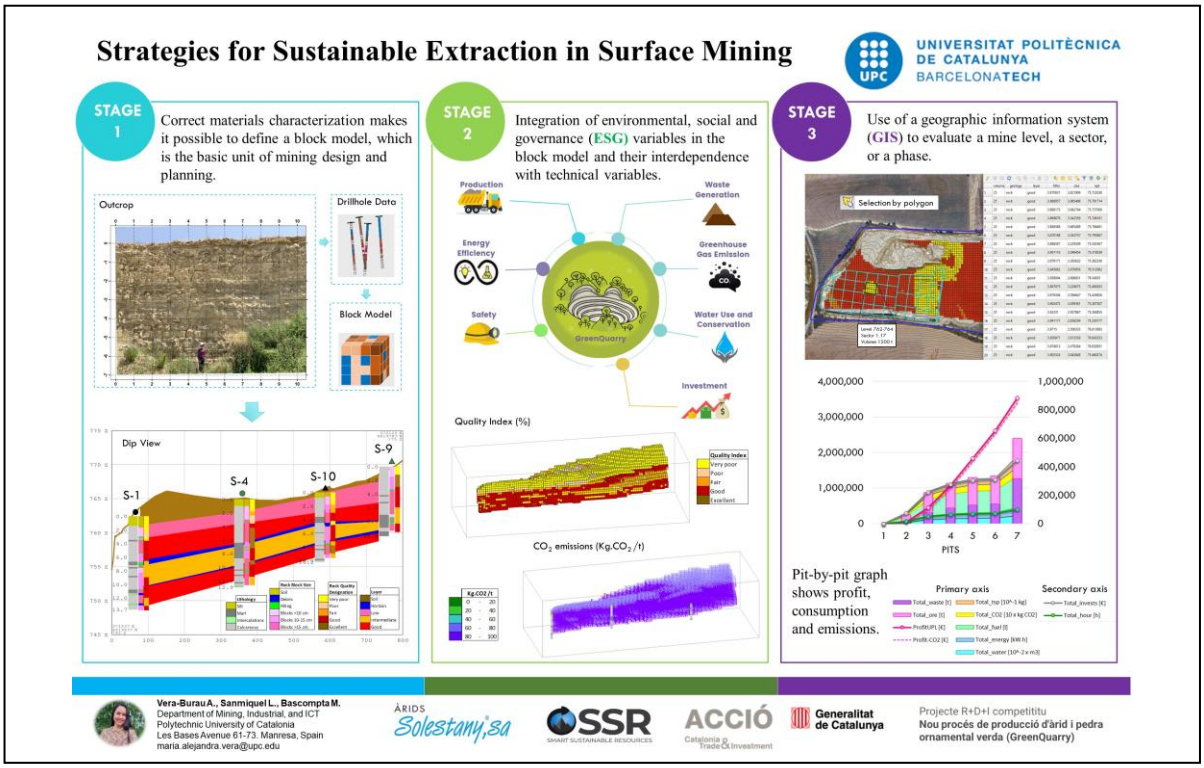
Keywords: green mining, quarries, ESG, GIS, environmental impacts.

Graphical Abstract



Surface mining operations face numerous challenges in the current context of environmental, technical, economic, and social conditions [1]. The incentive towards green mining must consider the industrial minerals and construction materials sector, as it represents the largest volume of resources required in the mining industry. Furthermore, this sector plays a pivotal role in technological advancement, social development, and fulfillment of the Sustainable Development Goals (SDGs). Adopting sustainable practices can contribute significantly to mitigating climate change, environmental protection, and using resources efficiently. Every now and then, surface mining activities, such as quarrying, are dominated by small-scale extraction. Moreover, in developed countries, open pit mining is usually focused on geological resources of low economic value (limestones, clays, sandstones, conglomerates, etc.). These materials are often crushed,

milled, and sized for aggregate production in the construction industry. Such a low economic value means that quarrying activities often do not receive the necessary attention in terms of studies, analysis of associated problems, and innovation. In addition, quarries can create significant negative impacts such as dust generation, noise, vibrations, and erosion, among others [2]. Generally, these impacts directly affect communities due to their proximity to projects, so establishing strategies is key for their correct development.

The modeling and assessment of quarries must be carried out in an exhaustive process, considering lithological, geomechanical, and physical characteristics. This is fundamental, since the reserves estimation process determines the life of the mine, and production, and has a direct influence on the design and planning [3]. Modeling should include indicators of the socio-environmental impacts generated such as water consumption, waste generation, man-hours required, accidents, and other variables [4], [5]. Therefore, this study proposes the establishment of a resource and production management system that is accessible to quarries of all types, providing estimates of impacts generated from early stages.

The aim is to identify and evaluate scenarios or alternatives to improve production or extraction efficiency and reduce, for instance, fuel consumption and CO2 emissions [6], using tools such as Life Cycle Analysis (LCA) [7]. In addition, encouraging circular economy practices, such as recycling construction materials and reusing quarry waste, can reduce environmental impact and operating costs, maximizing economic, environmental, and social benefits. Also, the goal is to contribute to stakeholders the adoption of more sustainable policies from early stages, like investing in environmental protection and human safety measures, as well as in technology, thus, the use of tools as the integration of environmental, social, and governance (ESG) aspects in this system is essential [8].

A new approach to the aggregates and ornamental rock production process is being suggested, introducing Geographic Information Systems (GIS) applications that allow adequate control and management of the quarries. This new framework will improve operational efficiency and promote a higher responsible and sustainable natural resource management by including socio-environmental impact indicators at each project phase.

Acknowledgment:

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Machine Learning Application in Real Bioleaching IIoT Systems for Metal Recovery

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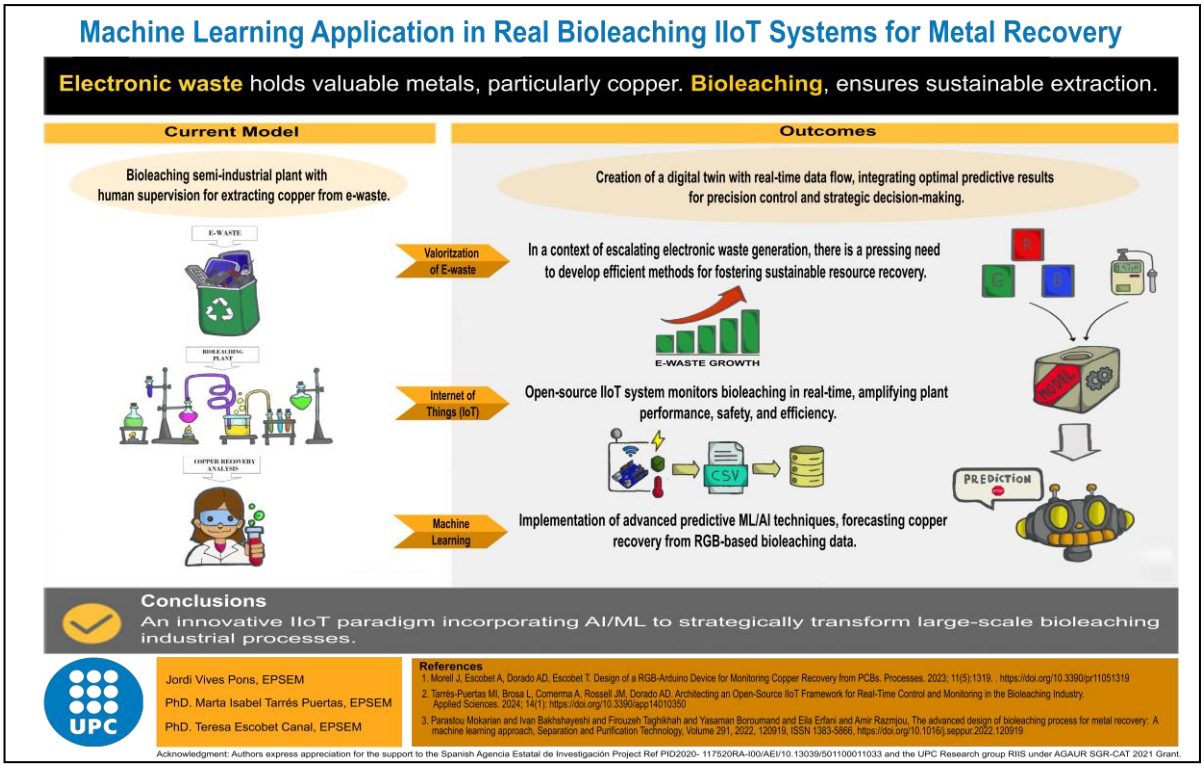
Keywords: bioleaching, color sensing, machine learning, metal recovery, real-time monitoring systems

Graphical Abstract



Introduction

This research focuses on the application of machine learning in real IIoT systems for metal recovery through bioleaching. The BIOMETALLUM project, led by the BIOGAP group at UPC, promotes a business model based on the circular economy, integrating emerging technologies of the Fourth Industrial Revolution to enhance the efficiency and sustainability of metal recovery processes from electronic waste [1].

Objectives

The primary objective of this project is to study, develop, and evaluate various linear regression algorithms to predict the volume of copper recovered and the RGB values in a real semi-industrial bioleaching plant. This involves analyzing different predictor variables and their effects on the predictions, as well as generalizing the model construction to facilitate testing with different sets of predictor variables and labels. Based on the results of this study, these algorithms will be utilized in the creation of a digital twin of the bioleaching plant, aimed at real-time process monitoring, optimization and evolution prediction. The ultimate goal is to develop a system that can be scaled up to large-scale industrial applications, optimizing the efficiency of metal recovery processes at a broader level.

State of the Art

The application of machine learning in bioleaching is a growing field with significant potential. Previous studies have demonstrated the feasibility of using machine learning models to optimize bioleaching processes through prediction of metal recovery rates, showing promising results in small-scale experiments. However, there are limited studies that integrate these models into real IIoT systems for large-scale applications. This project aims to bridge this gap by developing scalable machine learning models and integrating them into a semi-industrial bioleaching plant. By doing so, we aim to pioneer the use of digital twins in bioleaching processes, providing a robust framework for real-time monitoring and optimization.

Methodology

To implement the machine learning models, the Python programming language will be used along with some of the most common libraries for machine learning, such as pandas, scikit-learn, matplotlib, numpy, seaborn, statsmodels, and xgboost. The learning process will involve adjusting model parameters based on data obtained from the plant's sensors.

Initial experiments have involved collecting data on the relationship between the color of Fe(II)/Fe(III) and copper (Cu) concentration using the RGB sensors located in the production plant [3]. This data has been divided into two sets: training and validation (70%) and testing (30%). This division ensures that the model can learn patterns, validate performance, and test accuracy with unseen data.

During the training phase, the models to develop will use the training set to adjust its parameters and learn patterns in the data using optimization algorithms that minimize a loss function, measuring the difference between the model's predictions and actual values. Once trained, the models will be evaluated with the test set to determine generalization to new data and real-world accuracy. Additionally, overfitting and underfitting issues will be addressed.

Based on the results obtained from the analysis of published articles on bioleaching and machine learning [3], the following set of regression algorithms has been selected for development and evaluation:

- **Linear Regression:** Assumes a linear relationship between input and output variables, aiming to find the best-fit line that minimizes the sum of squared residuals.
- **Decision Tree:** Predictive models that split the data into smaller subsets based on input variables to maximize homogeneity in terms of the output variable.
- **Random Forest Regression:** An ensemble technique that combines multiple decision trees trained on random subsets of data and input variables to improve prediction accuracy.
- **Polynomial Regression:** An extension of linear regression that fits a polynomial to the data points, capturing more complex relationships.
- **Multilayer Perceptron (MLP):** A deep learning technique using interconnected layers of neurons to learn complex data patterns.
- **Support Vector Machine (SVM):** An algorithm that finds the best hyperplane in an N-dimensional space to separate classes.
- **Gradient Boosting Machine (GBM):** An ensemble decision tree method that builds trees sequentially, focusing on difficult-to-predict instances.
- **XGBoost:** An optimized implementation of GBM using techniques like parallel computing and data compression for improved speed and performance.
- **Adaboost:** An ensemble algorithm that improves weak models by adjusting data weights, focusing on incorrectly classified instances.

Performance indicators will include Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Pearson correlation coefficient (r), and the Coefficient of Determination (R^2). K-Fold Cross Validation will also be used to ensure models robustness.

Expected Results, Impact and Contributions

The project is expected to have a significant impact in several key areas:

- **Improved Energy Efficiency:** Accurate prediction of recovered copper volume will optimize the bioleaching process, saving energy and resources.
- **Implementation and Evaluation of Machine Learning Models:** Various models will be developed to predict RGB values and metal concentrations.
- **Predictive Information and Simulation:** Predictive tools will aid strategic decision-making, and simulation of different scenarios will evaluate plant performance.
- **Continuous Monitoring and Improvement:** Continuous monitoring of the digital twin will identify improvement areas and implement adjustments to ensure accuracy and reliability.

This project will optimize metal recovery processes and establish a platform for future experiments in a controlled environment, contributing to the development of emerging technologies in the Fourth Industrial Revolution. The implementation of a digital twin with optimal predictive results will enable more effective resource management, reduce waste, and improve the sustainability of industrial processes.

Publications and Conferences

Results will be published in indexed journals and international conferences related with AI engineering and computer engineering. The first results have been presented at "Modelling, Data Analytics and AI in Engineering" conference that will take place in Porto in July 2024.

Acknowledgment

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Sulfate reduction with hydrogen as the sole electron donor: biomass immobilization

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ABSTRACT

According to reports, hydrogen is the most favored electron donor in the process of sulfate reduction. However, due to the unique properties of hydrogen, its application in bioreactors poses significant challenges. This study aims to evaluate the application of sulfate-reducing bacteria (SRB) using laboratory-scale bioreactors, experiments, and simulations, with hydrogen as the sole electron donor and polyvinyl alcohol (PVA) as the bio-carrier in wastewater treatment. The objective is to optimize the activity and competitiveness of SRB while enhancing the mechanical strength and mass transfer properties of the bio-carrier. Additionally, we will develop a biofilm reactor and utilize mathematical models to validate and interpret the results. Currently, the experiment is in the testing phase of bacterial enrichment cultivation and biomass immobilization.

Keywords： SRB, Sulfate, Desulfurization, Hydrogen, Gas-Lift Reactor, Hydrogen Sulfide, BES, Anaerobic Reaction

OBJECTIVES

1. Activate sulfate-reducing bacteria (SRB) and maintain high activity to enhance the competitive potential of SRB against other microorganisms.
2. Optimize the mechanical strength of immobilized biomass using polyvinyl alcohol (PVA) as the biological carrier to reduce biomass loss within the bioreactor and maximize sulfate reduction efficiency.
3. Improve hydrogen mass transfer performance and optimize the bioreactor.
4. Characterization and modeling of the biofilm.

METHODS

- Bacterial Cultivation: Enrich sulfate-reducing bacteria (SRB) using a modified Postgate medium.
- Chemical Analysis Techniques: Gas Chromatography Analyze gas composition. Water Quality Analyzer Measure sulfide concentration and sulfate content.UV-Visible Spectroscopy with Coomassie Brilliant Blue Method: Conduct protein analysis to evaluate microbial growth status.

- 3D Printing Technology: Design a Membrane Biofilm Reactor (MBfR) using 3D printing technology.
- The development of bioreactors: Optimizing bioreactors using mathematical modeling

RESULTS

So far, this study has employed various chemical analysis methods to evaluate laboratory-scale cultures of sulfate-reducing bacteria (SRB), investigating the biomass retention and mechanical strength of polyvinyl alcohol bio-carriers. The methylene blue method has been utilized to assess biomass retention efficiency, while sulfate reduction efficiency and liquid-phase sulfur content have also been studied. The research findings can be summarized as follows: 1.Due to competition from various microbial communities, particularly methane-producing bacteria, inoculants obtained from wastewater treatment plants have shown a lower success rate in activating SRB. Additionally, centrifugation during the sampling process can damage SRB cells. 2.Biomass immobilization significantly enhances SRB retention and activity, with a notable improvement in the mechanical strength of the bio-carrier when mixed in a 2:1 ratio. 3.Substantial sulfide production was detected in each cycle of the experiment. In the short-term study, the feasibility of the experiment has been confirmed. Sulfate reduction rates of up to 90% have been achieved, with increased microbial activity and retention rates after biomass immobilization. The next step will involve transferring the research to bioreactors for further investigation.

CONCLUSIONS

Research has demonstrated the feasibility, cost-effectiveness, and environmental benefits of using biological methods to reduce sulfates in wastewater. However, a critical factor remains the activity and quantity of the required microorganisms. To address this issue, we have designed experimental control groups aimed at collecting data on microbial communities under various conditions, thereby building on previous studies to enhance sulfate reduction efficiency. Future research could focus on improving hydrogen mass transfer performance, genetically modifying sulfate-reducing bacteria, or developing automatic detection systems for reactors

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The Impact of Corporate Social Responsibility on the Extractive Sector: The Case of European Mining Firms

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Keywords: Corporate Social Responsibility, Microeconomics, Microeconomics, Mining, Total Factor Productivity, Sustainable Development.

In recent years, corporations have increasingly integrated social and environmental initiatives, leading to a stronger emphasis on Corporate Social Responsibility (CSR) strategies aimed at achieving sustainable development goals and securing a competitive edge in their markets [1]. Consequently, CSR and sustainability issues have garnered significant interest from researchers, executives, and decision-makers. Numerous academic studies have explored whether adopting CSR can enhance a company's financial performance. These studies generally demonstrate a positive correlation between CSR and the financial performance of mining firms, using indicators such as return on assets (ROA), return on equity (ROE), net profit margin (NPM), and Tobin's Q [2-3]. However, relying solely on financial metrics like ROA or ROE to measure the economic performance of the mining industry may not capture the full range of economic outcomes associated with mining activities. Therefore, this study advocated using total factor productivity (TFP) as a more comprehensive measure of economic performance in the mining sector. TFP

assesses the efficiency of converting inputs into outputs, encompassing both technical efficiency and technological advancement [4], thus providing a holistic view of economic performance by considering resource quantity and extraction efficiency.

This investigation employed a combination of Data Envelopment Analysis (DEA) to calculate and analyze the total factor productivity of European mining companies and panel regression to investigate the relationship between CSR and TFP. The sample includes 40 European mining companies from 16 countries. The overall findings indicate a positive correlation between CSR and TFP, with firm-level and macroeconomic indicators statistically impacting CSR. Moreover, the positive effect of CSR is predominantly driven by firm-level indicators, although the CSR-TFP relationship is also supported by macroeconomic indicators.

Our study makes several contributions to the literature. First, it measures mining industry performance on a microeconomic scale, known as technical efficiency. While existing literature, though limited, examines the link between CSR and firm performance in the mining industry using financial performance ratios [5], these ratios explain a company's strength from various monetary perspectives but are limited to a few variables. In contrast, total factor productivity can incorporate a wide range of variables to assess corporate performance, offering a multidimensional analysis that evaluates the production process at all stages.

The findings suggest that CSR initiatives positively affect the TFP of European mining firms. The empirical results also show that the CSR-TFP relationship is primarily based on institutional criteria. Additionally, CSR-related factors such as transparency and reporting, training, health and safety, and resource management are identified as significant indicators.

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AUTHORS INDEX

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B

C

D

E

F

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H

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L

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