From Mining Waste to Resource: A Transdisciplinary Pathway to a Smart and Sustainable Economy

Guglietta Daniela[1], Vanesa Silvani[2,3], Matías Barrionuevo[4,6], Ana Castaño Gañán[5], Adalgisa Scotti[1,5,6], Isabel Nogues [7], Laura Passatore[7], Matteo Paciucci[1], Rosalda Punturo[8]

1-Consiglio Nazionale delle Ricerche (CNR) – Istituto di Geologia Ambientale e Geoingegneria (IGAG)
2-Universidad de Buenos Aires, Facultad de Ciencias Exactas y Naturales, Departamento de Biodiversidad y Biología Experimental, Buenos Aires, Argentina
3-Universidad de Buenos Aires, Instituto de Biodiversidad y Biología Experimental y Aplicada (IBBEA), Buenos Aires, Argentina
4-IANIGLA-CCT CONICET Mendoza.
5-Comisión Nacional de Energía Atómica – ICES – Laboratorio Bioambiental – Facultad Regional San Rafael – Universidad Tecnológica Nacional- Grupo GAMA
6-Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Cuyo
7- Consiglio Nazionale delle Ricerche (CNR) – Istituto di Ricerca sugli Ecosistemi Terrestri (IRET)
8- Scienze Biologiche, Geologiche e Ambientali, Università di Catania

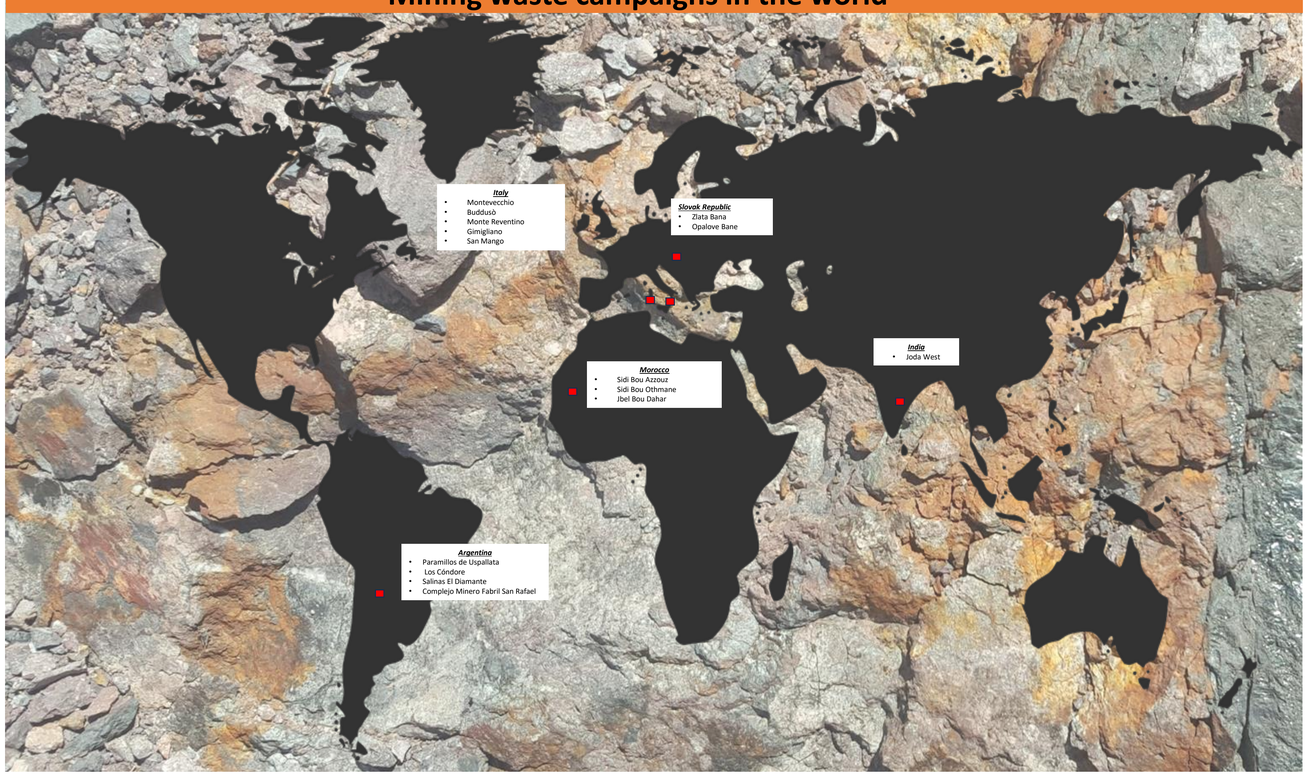
Introduction

The increasing scarcity of raw materials (RMs), resource depletion, rising metal prices, and environmental pressures have made RMs recovery from waste a global priority [1]. Mining waste, produced in vast quantities worldwide, represents both an environmental challenge and a potential resource [2]. Unlocking this potential requires accurate data on waste location and residual exploitable minerals, coupled with innovative recovery strategies [3].
Since 2014, our research group has conducted extensive mining waste sampling campaigns across Europe, Africa, India, and Latin America, within the framework of numerous national, European, and international projects.

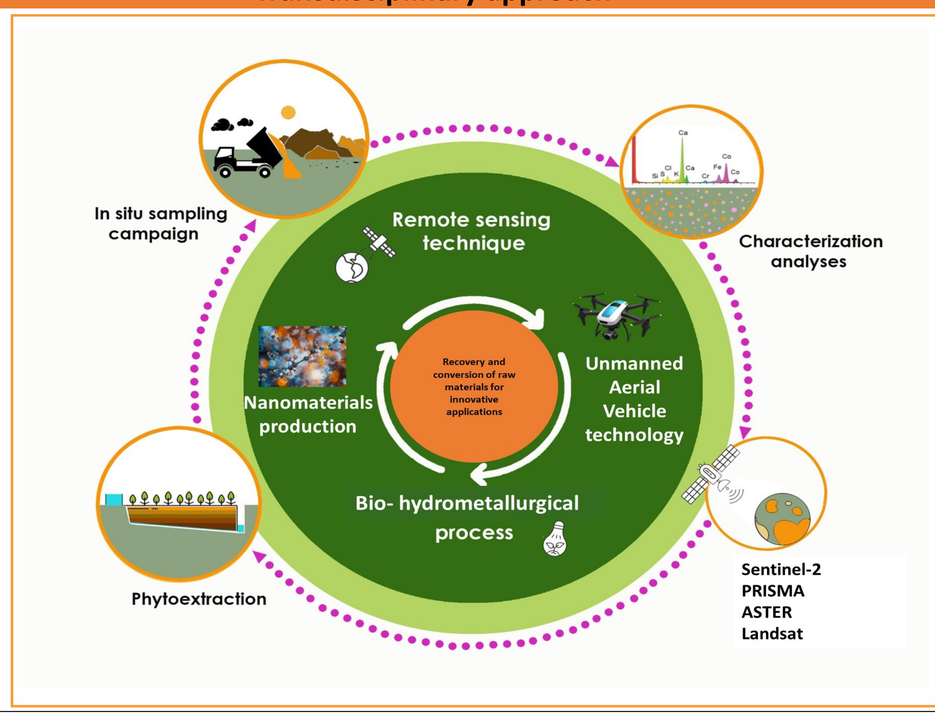
Aim

Over a decade of research and strong collaborations with universities, research centers, public institutions, and private enterprises have enabled the development of a transdisciplinary approach that integrates advanced spectral, chemical, and mineralogical characterization, satellite and drone mapping, and innovative phytoextraction assisted by mycorrhizal fungi and bio-hydrometallurgical processes.
This integrated methodology will be further applied to study areas in Argentina and Europe, where ongoing research aims to transform mining waste into a valuable resource and foster smart economy pathways for a sustainable future.

Mining waste campaigns in the world

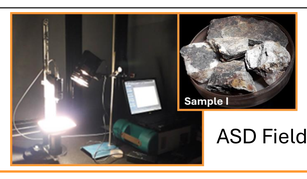


Transdisciplinary approach

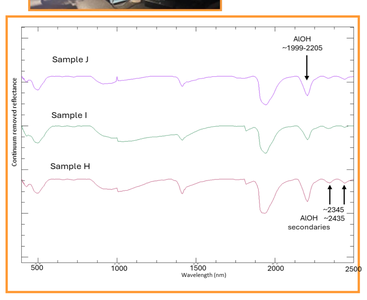


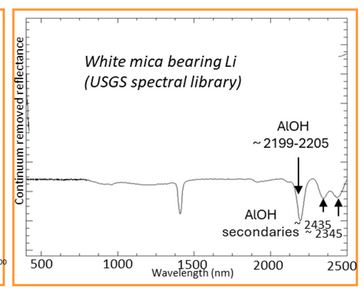
Work in progress

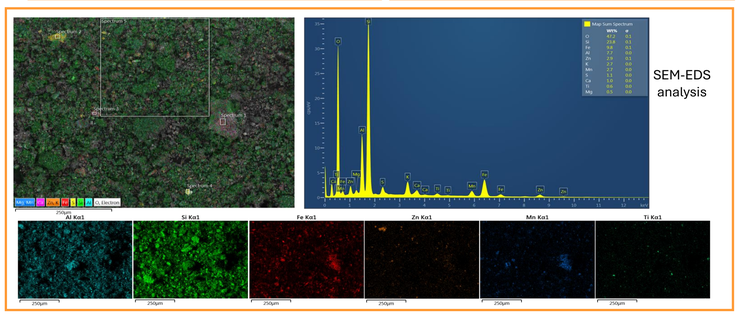
Los Paramillos mine- Argentina



ASD FieldSpec Spectroradiometer







SEM-EDS analysis

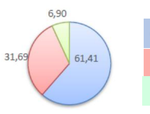
Salinas el Diamante- Argentina

In situ sampling campaign

Preliminary characterization analysis

- The Li values found in the salina (surface solid phase, deep solid phase; surface liquid phase; and deep liquid phase) ranged from 12 to 37 ppm, being higher in the deep liquid phase.
- The predominant plant species identified was Atriplex sp., whose Li uptake capacity and possible mycorrhization are being analyzed. Root plants did not show any mycorrhizal structures, but other fungal endophytes were recognized in Atriplex sp., which are typical of this extreme environments [4] .

Serpentinite quarries- Italy

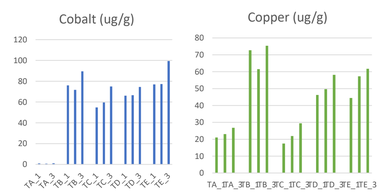


Grain size analysis

Greenhouse experiment (CNR- IRET, Rome)

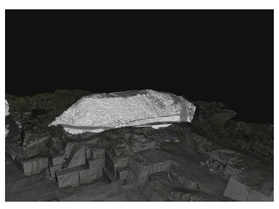
Pellet of biomass of sunflower for characterization analyses

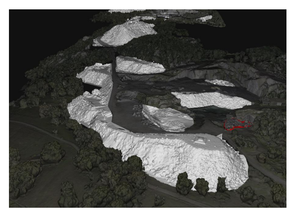
Preliminary results analysis by ICP-MS (Sapienza University- Rome)



Granite scraps- Italy

Drone-based reconstruction of waste accumulations (Università degli Studi di Ferrara)





Conclusions

Mining waste represents a potential source of RMs that the modern technologies and the availability of new equipment can valorize to ensure sustainable raw materials supply through circular use of resources. Future activities will include the creation of a geodatabase, the use of next-generation satellite and UAV (Unmanned Aerial Vehicle) technologies, and the application of phytoremediation assisted by mycorrhizal fungi and bio-hydrometallurgical processes, strengthening the role of mining waste recovery as a cornerstone of the circular economy.

References

[1] European Commission. Study on the Critical Raw Materials for the EU 2023- Final Report.

[2] European Commission (2020). Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability, COM (2020) 474 final.

[3] Guglietta D., Conte A.M., Paciucci M., Passeri D., Trapasso F. and Salvatori R. (2022). *Mining Residues Characterization and Sentinel-2A Mapping for the Valorization and Efficient Resource Use by Multidisciplinary Strategy.* Minerals, 12(5), 617; https://doi.org/10.3390/min12050617

[4] Cofré MN, Becerra AG, Nouhra ER, Soteras MF (2012). Arbuscular mycorrhizae and dark-septate endophytes on Atriplex cordobensis in saline sites from Argentina; J Ag Techn 8(7):2201-2214.