Analytical Characterization and Evaluation of Extractive Waste

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Introduction

The mining industry exerts significant and multifaceted impacts on the environment, including landscape degradation, soil and water contamination, and extensive land use. Among the most critical environmental challenges associated with mining activities is the generation of extractive waste, commonly referred to as tailings [1]. These materials are produced in large volumes during ore extraction and processing operations. The characterization and management of extractive waste are essential not only for minimizing environmental risks but also for identifying opportunities to recover valuable secondary resources [2]. A comprehensive understanding of the physical, chemical, and mineralogical properties of such waste contributes to sustainable resource utilization and supports regional environmental and economic resilience.

Materials and Methods

The extractive waste, originating from Poland, was characterized as a fine sand-like material generated as a by-product of mining activities. Oxide concentrations were determined using X-ray fluorescence (XRF), while anions were analyzed using ion chromatography (IC) to assess the material's chemical composition and the metals release in water with ICP-MS and ICP-OES.

Results

Oxide concentrations

Nr.	Type	Value	Units
1.	MgO	2.66	%
2.	Al_2O_3	3.00	%
3.	SiO_2	65.51	%
4.	K_2O	0.87	%
5.	CaO	0.21	%
6.	TiO_2	<LOD	%
7.	MnO_2	<LOD	%
8.	Fe_2O_3	0.51	%
9.	CuO	<LOD	%
10.	ZnO	<LOD	%
11.	SnO_2	<LOD	%
12.	Sb_2O_3	<LOD	%

Release in water

Nr.	Type	Value	Units
1.	As	0.010	mg/kg (DW)
2.	Cr	0.010	mg/kg (DW)
3.	Al	1.79	mg/kg (DW)
4.	P	0.24	mg/kg (DW)
5.	S	2.8	mg/kg (DW)
6.	Fe	1.16	mg/kg (DW)
7.	F	0.77	mg/kg (DW)
8.	Cl	2.65	mg/kg (DW)
9.	NO_2	< 0.5	mg/kg (DW)
10.	NO_3	< 2	mg/kg (DW)
11.	PO_4	< LOD	mg/kg (DW)
12.	SO_4	7.88	mg/kg (DW)

The waste sample showed a **high SiO_2 content (65.51%)**. Ion chromatographic results indicated **low levels of anions**, such as fluoride, chloride, and sulfate. These findings suggest that the material's **high silica content** and **low anionic load** render it suitable for **reuse in cementitious or construction materials**, supporting sustainable waste valorization.

Conclusions

The results of this study represent a significant step toward the sustainable utilization of extractive waste. Incorporating such materials into cementitious composites offers notable environmental benefits by reducing the volume of waste and minimizing potential soil and water contamination. Furthermore, the valorization of extractive waste within the region contributes positively to the local economy, supporting both environmental protection and resource efficiency.

References

1. E. Garbarino; G. Orveillon; H.G.M. Saveyn, Management of waste from extractive industries: The new European reference document on the Best Available Techniques, Resources Policy 69, 2020, https://doi.org/10.1016/j.resourpol.2020.101782
2. S. Mancini; M. Casale; A.Tazzini; G. A. Dino, Use and Recovery of Extractive Waste and Tailings for Sustainable Raw Materials Supply. Mining 2024, 4, 149–167, https://doi.org/10.3390/mining4010010

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