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COMPOSITION AND LEACHING CHARACTERISTICS OF MINING ASHES

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Introduction

The present study aims to evaluate the chemical and mineralogical compositions of ash samples from mining activities. Various experimental and theoretical studies have been carried out to correlate the chemical and mineral composition of coal ash with the determination of their behavior in the leaching process. Experimental techniques included XRF (X-ray fluorescence) analysis of the ash used to determine the elemental composition of the major oxides. The leaching behavior of the ash samples was determined by investigating the influence of pH, total dissolved solids (TDS) and Redox Oxidation Potential (ROP) at different values of contact time. PCA analysis was used to evaluate the elements that may indicate the potential for contamination and stabilization of the samples and to understand the behavior of the mining ashes and the phase transformations that occur during the leaching process.

Materials and methods

Ashes samples from industrial mining activities were collected from dumps stored in abandoned areas. The oxide composition of the calcined ashes was determined using a Rigaku X-ray fluorescence spectrometer. The analysis of metals in the solid samples and the extractable fraction was performed with the inductively coupled plasma optical emission spectrometry (ICP-EOS). The gravimetric (TDS, SO_4^{2-}), electrochemical (pH, F^-, ROP), combustion (N total, DOC), volumetric (TOC, Cl^-) methods were used to determine the parameters characteristic of the solid content and leachates of the analysed ash samples. PCA analysis is characterized by its capability to reduce the dimensionality of the data matrix while retaining most of the original information. Linear associations are applied to transform the original variables (X) into a limited number of new principal components (PCs). This chemometric approach determines the minimum number of PCs capable of describing the sum of squares of the data matrix. Component classes are defined by scores and loadings. A score contains all the information about an addressed topic (experiment, sample, etc.) and corresponds to a projection into the space of principal components. Loadings are projections of (x, y, z) variables into PCA space. This allows simultaneous interpretation of the relationship between sample characteristics and variables. PCA analysis and contour plots were generated with Number Cruncher Statistical Systems statistical software (NCSS 2021 v21.0.3).

Results and conclusions

The analysis of major oxides (Figure 1) in the processed ash samples determined a content of 37.1% Fe_2O_3, 5.16% Na_2O, 2.20% Al_2O_3 and 2.16% CaO.

The PCA analysis generated a first main component indicating a contamination potential supported by oxide minerals such as CuO, PbO, Sb_2O_3, ZnO, Na_2O, MnO, Al_2O_3, MgO and K_2O (Table 1) The second main component showed strong correlations between TiO_2 and CaO, elements used in the process of stabilizing combustion ashes in the mining industry.

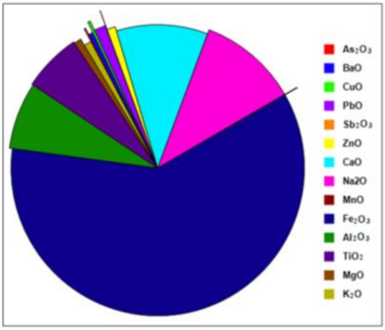

Fig. 1. Analysis of the major oxides in the processed ash samples

Table 1. Component Loadings after Varimax Rotation for major oxides

Variable	PC1	PC2	Variable	PC1	PC2
As_2O_3	**-0.7455**	0.2657	MnO	**-0.9588**	0.2771
BaO	0.5025	-0.5395	Fe_2O_3	**-0.7323**	0.6804
CuO	**-0.8634**	0.4687	Al_2O_3	**-0.9522**	0.2060
PbO	**-0.9495**	-0.0092	TiO_2	0.6063	**-0.7618**
Sb_2O_3	**-0.9092**	0.3071	MgO	**-0.8245**	0.5523
ZnO	**-0.9226**	0.3217	K_2O	**-0.9030**	0.3365
CaO	**0.0952**	**0.9410**	% variance	64.56%	28.15%
Na_2O	**-0.8024**	0.5689			

PCA analysis was applied to the characteristic parameters of the ash solid content and different leachates in extraction ratio of 1:2 and 1:10 (mass: volume), Table 2. The results obtained for the ash solid content showed a strongly positive loading of PC1 between the metals As, Pb, Sb and Fe and a strongly negative loading of Mn, Al, K, Na, Ca, Mg and F, with a percentage of 92.6% of the total variance and a decrease in TOC and Ntotal concentrations grouped in PC2. The PCA analysis of the leachates showed the suppression of the leaching potential of the toxic metals grouped in PC2 (27.5% of the total variant in the 1:2 extract and 35.7% in the 1:10 extract). The soluble species were grouped in PC1 with a percentage of 62.3% and 61.4% of the total variant. Fe leaches into the first extract, but this process is stopped at a higher dilution. The results obtained in the study of the leaching behavior of some ash samples from mining activities showed an increase in the concentrations of soluble species SO_4^{2-}, Cl^-, F^-, DOC, Ntotal, Ca^{2+}, Mg^{2+}, Na^{2+}, K^+ in the two extracts correlated with the decrease in the concentrations of toxic metals in the analyzed leachates.

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Table 2. Component Loadings after Varimax Rotation for solid ashes, leachate 1:2 (kg/L) and leachate 1:10 (kg/L) after 24h contact

Variable, mg/kg	**Solid**		**L 1:2** (24h)		**L 1:10** (24h)	
	PC1	**PC2**	**PC1**	**PC2**	**PC1**	**PC2**
As	**0.9551**	0.2427	-0.0896	**0.9660**	-0.1809	**0.9808**
Cr	-0.6467	-0.7433	-0.1245	**0.9837**	-0.0241	**0.9971**
Pb	**0.8058**	-0.4012	0.2115	**0.8184**	0.5882	-0.3211
Sb	**0.9588**	-0.2352	-0.6860	-0.7186	0.0839	**0.9844**
Zn	**-0.8626**	0.1979	**-0.7124**	**-0.7017**	-0.6140	0.7869
Cu	-0.5460	0.2747	-0.2511	**-0.9679**	**-0.7264**	-0.3765
Mn	**-0.9956**	0.0939	**-0.9995**	0.0252	**-0.9922**	0.0536
Al	**-0.9768**	0.1390	-0.3251	**0.8806**	-0.2259	**0.9585**
Fe	**0.9340**	0.1562	**-0.9474**	-0.2570	-0.5600	**0.8187**
K	**-0.9762**	0!1883	**-0.9252**	-0.2722	**-0.9144**	0.4046
Na	**-0.9430**	0.3270	**-0.9883**	-0.1516	**-0.9605**	0.2657
Ca	**-0.9865**	0.1045	**-0.8598**	0.2786	**-0.9326**	0.0355
Mg	**-0.9774**	0.2009	**-0.9988**	0.0456	**-0.9917**	0.0378
F^-	**0.8158**	-0.5773	**0.9272**	0.3175	**0.8817**	-0.3885
SO_4^{2-}	-0.6192	**0.7712**	**-0.9514**	-0.1758	**-0.7343**	0.6493
Cl^-	-0.4951	0.6039	**-0.7674**	-0.6114	**-0.7872**	0.5946
TOC/DOC*	0.3817	**-0.8667**	**-0.9841***	-0.1770*	**-0.9289***	0.2841*
Ntotal	-0.2953	**-0.8530**	**-0.9371**	-0.3450	**-0.9472**	0.3170
TDS	-0.6528	0.7547	**-0.9000**	-0.3758	**-0.7163**	0.6774
% Variance	92.60%	6.32%	62.30%	27.50%	61.40%	35.70%

*TOC for Solid, DOC for leachates