Circular Economy in Iron Ore Mining: Least Squares Approach to Kaolinite Estimation of argillaceous waste material

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# ABSTRACT

Waste materials from mining operations may have characteristics that make them economically viable for use in other industrial sectors. Analyzing the properties of these materials adds value to projects and promotes regional circular economic initiatives, optimizing the use of mined resources. This study focused on an iron mine where the primary waste material is altered rock derived from basalts and dikes with similar composition. The weathering product of these rocks, referred to as weathered mafic (DM), predominantly comprises clay minerals (kaolinite) and iron hydroxides (goethite).

weathered mafic exhibits properties that make it promising for applications in civil construction. Specifically, material with kaolinite concentrations exceeding 40% can be used as a pozzolanic material, allowing up to 30% of cement to be replaced in mixtures. This substitution significantly reduces limestone consumption and, consequently, CO₂ emissions in the cement industry.

This study aimed to infer the mineralogy of weathered mafic, with a focus on kaolinite proportions, in all samples from a geological database. The normative mineralogical calculation was performed using an alternative method based on Least Squares (LS) to determine the proportions of constituent minerals, minimizing the quadratic error between the analyzed chemical contents and the chemical contents calculated from the mineralogical norm. The method does not require prior knowledge of the mineralogical sequence, relying solely on the mineralogical context of the analyzed samples.

The methodology was validated by comparison with results obtained via X-Ray Diffraction (XRD) using the Rietveld method, showing correlations above 0.8 and average relative differences below 5%. After validation, the approach was applied to drill hole databases and block models, proving crucial for predicting kaolinite distribution in mining scheduling. Additionally, absolute density was calculated, which can be used as a weighting variable in mineral resource estimation.