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Comprehensive Characterization of Steel Furnace Slag and Assessment of Pre-Treatment Efficiency for Wet Magnetic Separation: towards the valorization and reuse of magnetically isolated fractions

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Global steel production has shown continuous growth over time, largely driven by industrialization and urbanization processes. Pyrometallurgical processing of mineral ores produces a large volume of metal-bearing waste (slag). Due to the presence of magnetic iron oxides, these by-products could not only be reused in steel production but also aid in the generation of novel materials. In this study, a steel furnace slag was fully characterized and magnetically separated considering 1 and 2-hour calcination at three different temperatures (400, 600 and 800 °C) and ultrasonication as pre-treatments. The characterization of the raw slag and the products after the pre-treatments allowed us to evaluate their morphology, phase composition, magnetic response and hyperfine parameters. Altogether, this information enabled the assessment of the effectiveness of the pre-treatments on improving the wet magnetic separation process. XRD results of treated samples showed a reduction in the intensity of the peaks corresponding to the main iron oxide phase on the raw slag (wüstite) and an increase in the magnetite reflections, considering both holding times during thermal treatments. Mössbauer spectroscopy confirmed that the increment in the pre-treatment temperature to 600 °C and 800 °C, either during 1 or 2 hours, generated a principal iron phase transformation into magnetite. The saturation magnetization value determined for the raw slag was 2.7 Am^2/Kg, while the products of the thermal treatments presented values of 2.7, 5.7, 10.0 Am^2/kg and 2.9, 6.7, 9.6 Am^2/kg for samples calcined at 400, 600, and 800 °C during 1 and 2 hours, respectively. These results indicate that the pre-treatments yielded a material that is more responsive to an external magnetic field. In fact, the processes performed at 600 °C and 800 °C improved the segregation of magnetic phases, resulting in recovery mass percentages of around 80%, which are considerably higher than those obtained from the wet magnetic separation of untreated slag. These findings positioned this by-product as a suitable candidate for a phase transformation, boosting its magnetic response and improving the efficiency of separation. The assayed pre-treatments generated favorable changes in the slag, increasing its magnetite content and consequently its magnetic response, which helped to improve the yield during the magnetic separation.