Nano 2024 Innovation Rome, 9-13 September
Conference & Exhibition

Transforming red mud waste into valuable nano-magnetic materials: a comprehensive study

NanoInnovation 2024

Red Mud (RM) is a significant industrial byproduct derived from the production of primary aluminium, with an annual generation rate of approximately 200 million tons. The management and utilization of RM present substantial environmental challenges due to its high alkalinity and large volume. Therefore, finding innovative ways to repurpose RM is crucial for sustainable industrial practices and environmental protection. This study explores the reduction of RM to produce magnetic materials with peculiar chemical and physical properties suitable for applications in wastewater treatment, CO_2 capture, catalysis, and sensing. The reduction of RM was conducted in a semi-closed reducing environment at high processing temperatures ranging from 750 to 1100°C in presence of a carbon-rich ash (CA), a waste of a commercial pyro-gasification plant. The properties of the obtained materials were compared with those of materials obtained by a hydrogen (H_2) reduction process. All the produced materials were characterized using many analytical techniques, including elemental analysis, X-ray diffraction (XRD), scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM/EDX), thermogravimetry, and infrared spectroscopy. The materials synthesized under different conditions shared the common feature of containing small iron-magnetic domains, typically in the order of hundreds of nanometres. These domains exhibited various iron oxidation states and demonstrated either ferromagnetic or paramagnetic responses to an external magnetic field. Specifically, RM pre-treated with hydrochloric acid (HCl) and reduced with hydrogen showed enhanced magnetic properties. This treatment resulted in a higher concentration of iron in reduced oxidation states, leading to significant ferromagnetic responses. The diverse properties of the synthesized materials indicate their potential for multiple applications: as sorbents for specific pollutants in wastewater treatment, as materials capable of capturing CO_2, as catalysts to enhance reaction rates in chemical processes, and as sensors for detecting biological and chemical substances. Despite these promising applications, the high interconnection between magnetic and non-magnetic phases presents challenges for the direct separation and iron enrichment. Addressing these challenges will be essential for optimizing the usability of the materials. Future efforts will focus on detailed functional studies to better understand the best field of employ of the proposed materials. Additionally, life cycle assessment (LCA) and life cycle cost (LCC) analyses will be conducted to evaluate the environmental and economic viability of the processes and applications.