Valorization of bauxite mining waste for various applications

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Abstract

Red mud, or bauxite residue, is the primary waste product of the Bayer process used in the production of alumina from bauxite ore. This material is rich in iron oxide (Fe2O3), alumina (Al2O3), silica (SiO2), titania (TiO2), sodium (na2O), and trace elements, so it is viewed not only as alkaline waste but also as a secondary source of industrial raw materials. In Indonesia, the volume of red mud generated is significant due to the ongoing expansion of the bauxite processing industry. A recent study indicates around 1.95 million tons of red mud annually. Each ton of alumina typically generates approximately 0.8–1.5 tons of red mud.

Red mud processing generally begins with separation from the Bayer solution, washing to reduce caustic soda content, drying, neutralization, and stabilization. Subsequent stages may include size classification, calcination, magnetic separation, acid leaching, base leaching, precipitation, solvent extraction, or hydrothermal processes. This processing aims to reduce alkalinity, improve physical properties, separate valuable metals, and tailor the material's characteristics to the end application.

The utilization of red mud spans several fields. In the construction sector, red mud can be used as an additive in cement, bricks, concrete, geopolymers, paving blocks, ceramics, lightweight aggregates, and soil stabilization materials. Its Fe_2O_3 and Al_2O_3 content supports pozzolanic reactions and the formation of an aluminosilicate matrix. In the environmental sector, modified red mud can function as an adsorbent for phosphates, heavy metals, dyes, radionuclides, and organic contaminants. In metallurgy, red mud has the potential to serve as a source for the recovery of iron, titanium, aluminum, scandium, and rare earth elements. Additionally, red mud is being studied as a catalyst, catalyst support, pigment, gas-absorbing material, and heat storage material.

With proper processing, red mud can support the circular economy, reduce the need for landfill space, mitigate pollution risks, and generate value-added products for the national industry through the integration of research, policy, and sustainable commercial-scale operations.

Keywords: valorization; bauxite mining waste; red mud; appplications; circular economy