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Waste to value – a pilot demonstration and economic analysis of vaterite calcium carbonate production using brine, CKD, and CO_2

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ABSTRACT

This study presents a pilot-scale demonstration and techno-economic assessment of producing high-purity vaterite-type calcium carbonate ($CaCO_3$) through indirect carbonation, by utilising seawater reverse osmosis (SWRO) brine, cement kiln dust (CKD), and captured carbon dioxide (CO_2). A 50-ton-per-annum (TPA) pilot plant was constructed and operated in Jubail, Saudi Arabia, producing spherical vaterite $CaCO_3$ with verified purity and whiteness suitable for premium industrial applications. CKD provided the calcium source (40%–60% CaO content), while brine served as an effective solvent, eliminating the need for synthetic chemicals. CO_2 was directly injected to precipitate vaterite $CaCO_3$, achieving the major quality targets of ≥97% $CaCO_3$ purity, ≥80% vaterite content, ≥99% whiteness, and ≤3 μm particle size. Economic analysis for a scaled-up 100,000 TPA plant revealed a highly attractive internal rate of return (IRR >60%) and short return on investment (ROI <1.5 years), even under conservative market and CO_2 pricing assumptions. The process also demonstrated substantial greenhouse gas (GHG) reduction potential, particularly when integrated with low-carbon electricity. This work highlights a practical pathway for valorising desalination brine, utilising industrial waste, and enhancing CO_2 utilisation through the production of value-added vaterite $CaCO_3$.

Keywords: Indirect carbonation; Beneficial use of desalination brine; Vaterite; Calcium carbonate; Carbon capture utilisation and storage (CCUS); Brine valorisation

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