CIRCULAR ECONOMY OF THERMAL OILY SLUDGE MANAGEMENT FOR LOW-CARBON RENEWABLE ENERGY PATHWAYS

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Abstract - Oily sludge (OS), a hazardous byproduct of the petroleum industry, poses significant environmental and health risks due to its hydrocarbon pollutants. Managing OS is costly and complex, yet it offers opportunities within a circular economy framework that transforms waste into resources. This study evaluates thermal treatment of pyrolysis and thermal cracking methods for their effectiveness in degrading OS while monitoring emissions of CO, CO_2, SO_2, NO_2, and hydrocarbons against Omani regulations and USEPA standards, with results showing high compliance. Laboratory analysis of OS samples revealed an average of 5000 mg/kg (0.5%) total petroleum hydrocarbons (TPH), highlighting the urgency for effective treatment. Pyrolysis demonstrated strong potential to reduce hazardous components and generate usable byproducts. The resulting carbonaceous residue (black carbon) was characterized for reuse in construction, cement manufacturing, and soil improvement, creating industrial value chains. Renewable-energy integration, including solar thermal collectors and recovered hydrocarbon gas, was explored to reduce fossil fuel use and greenhouse gas emissions. Supported by emission modeling (CHEMCAD, AERMOD) and a case study from Oman, the findings provide a comparative evaluation of thermal technologies, practical pathways for black carbon valorization, and policy guidance. The study proposes an integrated management framework for sustainable OS treatment and low-carbon solutions.

Keywords - Oily sludge, TPH, Thermal treatment, Emissions, Black carbon, Circular economy, Sustainable solutions