

INTI SARI

Pertumbuhan kendaraan listrik (EV) dan perangkat elektronik portabel meningkatkan permintaan baterai LIB NMC (*Nickel Manganese Cobalt*) yang memiliki kepadatan energi tinggi dan umur pakai panjang. Peningkatan penggunaan ini diperkirakan menghasilkan 11 juta ton limbah baterai bekas pada 2030, yang menimbulkan masalah lingkungan dan keterbatasan pasokan logam strategis (Li, Ni, Mn, Co). Proses hidrometalurgi berbasis *leaching* menjadi metode daur ulang yang menjanjikan, namun penerapannya menghadapi kendala teknis seperti konsumsi air tinggi dan pengaruh residu Na₂SO₄ serta H₂O₂ terhadap efisiensi *leaching*.

Penelitian ini bertujuan mengevaluasi pengaruh konsentrasi H₂O₂ dan Na₂SO₄ terhadap efisiensi leaching logam Li, Ni, Mn, dan Co dari black mass baterai bekas NMC. Proses dilakukan menggunakan H₂SO₄ 1,8 M dengan variasi H₂O₂ (1; 2; 3%), Na₂SO₄ (0,08; 0,17; 0,33 M), dan suhu (40; 60; 80 °C) selama 30 menit. Rasio padatan terhadap larutan dijaga sebesar 120 g/L dengan kecepatan pengadukan 500 rpm. Karakterisasi awal *black mass* dan hasil filtrat dianalisis menggunakan ICP-OES untuk menentukan kandungan logam dan tingkat *recovery*.

Hasil penelitian menunjukkan bahwa *black mass* mengandung Li, Ni, Mn, dan Co berturut-turut sebesar 10,30%; 41,08%; 22,28%; dan 15,47%. Kondisi optimum *leaching* dicapai pada H₂O₂ 3%, Na₂SO₄ 0,08 M, dan suhu 80 °C dengan *recovery* maksimum masing-masing logam sebesar 93,74%; 88,15%; 91,52%; dan 91,43%. Pemodelan kinetika menggunakan pendekatan *Shrinking Particle Model* (SPM) mengindikasikan bahwa tahap pengendali adalah reaksi kimia.

Kata kunci: Baterai NMC bekas, daur ulang, hidrometalurgi, hidrogen peroksida, natrium sulfat, asam sulfat

The growth of electric vehicles (EVs) and portable electronic devices has increased the demand for NMC (Nickel Manganese Cobalt) lithium-ion batteries (LIBs), which offer high energy density and long cycle life. This rising use is projected to generate up to 11 million tons of spent batteries by 2030, leading to environmental concerns and the depletion of strategic metal resources (Li, Ni, Mn, Co). Hydrometallurgy based on leaching has emerged as a promising recycling method; however, its implementation faces technical challenges such as high water consumption and the influence of Na₂SO₄ and H₂O₂ residues on leaching efficiency.

This study aims to evaluate the effect of H₂O₂ and Na₂SO₄ concentrations on the leaching efficiency of Li, Ni, Mn, and Co from the black mass of spent NMC batteries. The process was conducted using 1.8 M H₂SO₄ with variations of H₂O₂ (1, 2, 3%), Na₂SO₄ (0.08, 0.17, 0.33 M), and temperature (40, 60, 80 °C) for 30 minutes. The solid-to-liquid ratio was maintained at 120 g/L with a stirring speed of 500 rpm. The initial characterization of the black mass and the filtrate was analyzed using ICP-OES to determine metal content and recovery rates.

The results showed that the black mass contained Li, Ni, Mn, and Co at 10.30%, 41.08%, 22.28%, and 15.47%, respectively. The optimum leaching condition was achieved at 3% H₂O₂, 0.08 M Na₂SO₄, and 80 °C, resulting in maximum recoveries of 93.74% (Li), 88.15% (Ni), 91.52% (Mn), and 91.43% (Co). Kinetic modeling using the Shrinking Particle Model (SPM) indicated that the rate-controlling step was the chemical reaction.

Keywords: Spent NMC batteries, recycling, hydrometallurgy, hydrogen peroxide, sodium sulfate, sulfuric acid