

Advancing Sustainable Polyethylene Terephthalate (PET) Recycling through Subcritical Water Hydrolysis: Process Optimisation and Environmental Evaluation

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Abstract

Polyethylene terephthalate (PET) is a major packaging material whose low recycling rate continues to contribute to global plastic waste accumulation. Conventional recycling routes such as mechanical reprocessing and glycolysis face persistent challenges including feedstock contamination, product downgrading, and high material input. Subcritical water hydrolysis offers a cleaner and more sustainable alternative, utilising only water at elevated temperature and pressure to recover terephthalic acid (TPA) and ethylene glycol (EG) without added catalysts or organic solvents.

This study investigates the process behaviour and environmental performance of PET hydrolysis in subcritical water within the temperature range (225 - 300) °C using both virgin and post-consumer feedstocks. Process parameters including temperature, residence time, agitation, PET-to-water ratio, and heating rate were systematically varied to determine conditions for efficient depolymerisation and high-purity product recovery. Optimal performance was achieved at 275 °C, yielding complete PET conversion within 20 minutes and direct recovery of >97% pure TPA by filtration without chemical purification.

Environmental and sustainability assessment was conducted using the E-factor and energy economy coefficient as comparative metrics. Results indicate minimal waste generation and favourable energy utilisation relative to conventional chemical recycling methods such as glycolysis and methanolysis. The absence of catalysts and solvents further improves the environmental profile, while trials with post-consumer PET confirmed robustness to real waste variability.

Scalability assessment identified continuous flow operation and heat recovery integration as essential to achieving industrial energy efficiency. The findings demonstrate that neutral hydrolysis in subcritical water provides a resource-efficient and low-impact route for PET recycling, supporting circular economy targets and reducing dependence on virgin plastic feedstocks.

Keywords

Recycling, hydrolysis, plastics, sustainability, process optimisation, energy efficiency, circular economy, waste management, environmental impact, scale-up.