Advances in Recycling and Resource Recovery of Post-Consumer Polyethylene Terephthalate (PET) Waste for Sustainable Waste Management and Circular Economy

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Abstract

Polyethylene terephthalate (PET) is widely used in textiles, packaging, and consumer goods; however, its extensive consumption has led to significant environmental challenges due to post-consumer waste accumulation. This review explores recent advancements in PET recycling, focusing on chemical and enzymatic methods as sustainable alternatives to traditional mechanical recycling. Chemical recycling processes, including glycolysis, methanolysis, and hydrolysis, break PET into monomers, enabling the production of high-quality recycled materials. Enzymatic recycling, utilizing PET-degrading enzymes, offers an eco-friendly approach with mild reaction conditions and high specificity. The review compares these methods in terms of efficiency, scalability, energy requirements, and life cycle assessments (LCAs), highlighting enzymatic recycling's lower environmental impact. Additionally, economic feasibility and large-scale implementation challenges, including contamination and cost-effectiveness, are discussed. Despite technological advancements, further innovation and policy support are essential to optimize these recycling strategies, foster a circular economy, and mitigate PET-related environmental pollution.

Keywords: waste polyethylene terephthalate, sustainable recycling techniques, high-quality products, reducing carbon dioxide (CO2) emission.

Significance | Innovative PET recycling methods enhance sustainability by reducing waste, conserving resources, and promoting circular economy goals through mechanical, chemical, and bio-recycling advancements.

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1. Introduction

Polyethylene terephthalate (PET) is a commonly recognized and essential material in industries such as containers, packaging materials, and textiles owing to its valuable properties of low cost, mechanical robustness, high stain resistance, and low permeability. According to Statista, the global PET production volume reached 25.47 million metric tons in 2022 and is expected to grow at a compound annual growth rate of 4.1% by 2030, resulting in a total market volume of 35.70 million metric tons by 2030(Statista Research Department, 2024, Uekert et al., 2019). Although PET's widespread use has driven industrial growth shown in Figure 1 and it has also resulted in a significant increase in post-consumer waste PET creates substantial environmental challenges. To address this, effective management of waste PET is vital for reducing pollution, conserving resources, and promoting sustainability, alongside the goals of a circular economy that focuses on material reuse and waste reduction. Additionally, traditional recycling methods, such as landfilling and incineration, are unsustainable, leading to resource depletion, pollution, and greenhouse gas emissions (Hajam et al., 2023, Salvador et al., 2019). Consequently, an urgent need for

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