BATCH AND CONTINUOUS LOW-PRESSURE HYDROTHERMAL PROCESSING METHODS FOR POLYSTYRENE CONVERSION TO OILS

by

Clayton Clarkson Gentilcore

Abstract:

Annual rates for global polystyrene (PS) waste accumulation have reached 28 million tons, yet recycling rates remain around 1%. Conventional waste treatment methods have proven largely ineffective in reducing PS waste accumulation. As PS waste degrades, it generates microplastics and releases harmful chemicals that impact human health and ecosystems. This study developed batch and continuous low-pressure hydrothermal processing (LP-HTP) methods to convert PS into oils. In the batch LP-HTP study, the effects of temperature, time, and water loading on oil yield and composition were evaluated. The process converted PS to 96–99% oils with minimal char formation (1–2%) while requiring no catalyst, outperforming traditional pyrolysis. The LP-HTP methods also require lower energy inputs and pressures than supercritical water liquefaction. Co-processing PS with polyolefins resulted in oil yields of 87% and higher aromatic contents compared to polyolefin-only oils. Monomer (C_6–C_9) yields were limited by reversible reactions with poly-aromatics (C_{10}–C_{24}). Efficient continuous LP-HTP methods were then developed, achieving 99% oil yields at 0.2–1.2 kg/hr under atmospheric pressure. The oil contained styrene monomers, dimers, and trimers with a total yield of 89% at 389°C. A detailed kinetic model was constructed, with intrinsic parameters estimated from continuous conversion data to enable process optimization and scale-up. These LP-HTP methods show potential for reducing environmental impacts and achieving up to 4.7 times higher energy recovery than incineration. The resulting hydrocarbons, if separated into pure monomers, can be used as chemical feedstocks, supporting a circular hydrocarbon economy that incentivizes plastic waste conversion.