Pyrolysis of Iron-Impregnated Plastic Solid Waste

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Abstract
The increasing amount of plastic solid waste (PSW) is primarily due to its high production rates and non-biodegradable nature. However, despite significant advancements in recycling technologies, landfilling and incineration remain the most used PSW treatment methods. Among viable alternatives, pyrolysis has emerged as an environmentally friendly solution for treating PSW and producing value-added co-products using high temperatures in inert environments. Breaking down the long polymeric chains, this thermochemical process yields three main co-products: a solid residue (pyro-char), a liquid fraction, and a gaseous fraction. While the potential of liquid and gas products as alternatives to fossil fuels has been widely studied, pyro-char has received little attention. This study, therefore, investigates the characteristics of pyro-char obtained from polyolefin densification waste and explores the effects of metallic pre-impregnation on its properties. Iron, an abundant and inexpensive metal, was selected for its potential auto-catalytic role in enhancing gas and oil production while producing a pyro-char with catalytic applications. PSW was impregnated with iron acetate (0, 5, 10, 15, 20, and 25 wt%) and pyrolyzed at 900°C and 1000°C for 2 hours. These preliminary tests revealed an unexpected trend: at 10 wt%, the pyro-char yield reached a minimum at 900 °C and a maximum at 1000 °C. To further understand this behavior, other tests were conducted at 600, 700, 800, and 1100 °C keeping the iron acetate concentration at 10 wt%. Although pyro-char yield generally decreased with increasing temperature, a sharp local minimum reappeared at 900 °C, indicating a complex interplay of thermal and catalytic effects. Crystalline particles were detected in all impregnated residues via Scanning Electron Microscopy (SEM). The presence of crystalline structures was further confirmed by Transmission Electron Microscopy (TEM) and X-ray Diffraction (XRD), which suggested the production of iron carbides and oxides as confirmed by the Energy-Dispersive X-ray Spectroscopy (EDS). However, their concentration and behavior during pyrolysis treatment still remains under investigation as it represents a fascinating but complex topic. Additional tests at 900 °C with varied residence times will aim to clarify kinetic effects as an in-depth comprehension of the analysis results. These findings reveal complex iron–PSW interactions during pyrolysis and suggest new pathways to enhance pyro-char functionality via metal-assisted processes.