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Composition analysis of ultrapyrolytic recycled products from various brands of ultra-heavy mining truck waste tires

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Off-the-road (OTR) waste tires of heavy mining dump trucks have devastating environmental effects. They are also a reliable source of some valuable raw materials, which could be returned to the manufacturing process by recycling. Pyrolysis is a promising and eco-friendly approach for recycling big, heavy tires. This paper aims to use a laboratory-scale reactor to investigate the pyrolysis process and analyze the recycled pyrolytic yields of OTR ultra-heavy mining waste tires in large Iranian open pit mines. After developing the pyrolyzer set up in a laboratory, eight popular tire brands used in open-pit mine dump truck fleets were selected and collected as the sampling population. Smaller samples were prepared by cutting and downsizing them into small pieces. Each tire brand was then processed under pyrolysis conditions with operating parameters including the batch weight of 2.5 kg, the maximum temperature of 600 °C, and residence time varying from 120 to 173 min based on the specific tire brand. The percentage of the main products are fuel oil (31–36%), non-condensable gases (10–13%), carbon black (31–38%), and steel wire (18–25%). The results show that the thermochemical decomposition of OTR mining waste tire samples occurs within a temperature range of 300–400 °C, proceeding through three distinct degradation phases (oil, char, and gas). As the temperature increased, due to secondary cracking reactions in volatile matter, the oil yield fell while gas yield rose in the same order. Analysis of the produced pyrolytic oil and char suggests that both products have potential applications as fuels. Moreover, the FESEM images of recycled carbon black from all studied samples show the coalesced nanoparticles, sugar fabric, and porous media due to the desulfurization process. This paper's outputs could primarily be applied for developing any pilot or industrial plant for tire recycling in Iran and economic analysis of investment return rate as well.

Keywords OTR ultra-heavy mining truck waste tire, Recycling, Pyrolysis, Environment

Ultra-heavy dump trucks are extensively used in large open-pit mining operations and rely on massive off-the-road (OTR) tires with limited lifespans. These tires constitute a significant portion of operational costs, up to one-third in some cases, and are a major source of solid waste in mining operations[1–3]. Globally, around 800 million OTR tires are discarded annually[1,4]with mining trucks being responsible for 15–20% of this volume[5]. Nowadays, the removal of mining OTR tires is an environmental concern. Due to their large size (2–4 m in diameter, over 3 tons in weight) and complex chemical structure[6–8]these tires are difficult to transport, nearly non-biodegradable, and pose serious environmental risks if improperly disposed[4,9,10]. In many regions, OTR tires are left, stockpiled, or sometimes openly burned (Fig. 1), leading to soil and groundwater contamination and the release of hazardous pollutants and greenhouse gases[11–19].

To address these challenges, environmentally sustainable recycling methods are essential. Several approaches have been developed for managing OTR waste tires, including rubber powder production, tire retreading, landfilling, and pyrolysis[21]. Among these, pyrolysis has emerged as a particularly promising solution, offering waste reduction, resource recovery and decreasing air pollution. This thermochemical process breaks down tire components into valuable byproducts such as fuel, carbon black, and gas, making it a key technology for the sustainable management of ultra-heavy OTR waste mining tires. Based on the heterogeneity in tire compositions across manufacturers, the primary research question is whether differences in the brand of ultra-heavy OTR

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