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An investigation of the thermal degradation mechanisms of a waste tire through chemical analysis including hydrocarbons, benzene derivatives, and Polycyclic Aromatic Hydrocarbons (PAHs) at high temperature

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ABSTRACT

Previous work has focused on a series of fundamental Thermal Gravimetric Analysis (TGA) studies using representative atmospheres found in Waste-to-Energy (WtE) boilers. Those studies were done for waste tires and their major constituents, such as Styrene-Butadiene Copolymer (SBR) and Poly-Isoprene (IR). The outcome has been the elucidation of the likely mechanism responsible for initial decomposition, final product and byproduct formation. To extend that understanding to a more practical level, a flow through apparatus has been used to test waste tire samples in the temperature range of 500˚C-800˚C. A chemical analysis in this temperature range has been performed to compare the thermal degradation mechanism and air pollutant generation in low temperature regimes. The release of chemicals from a tubular quartz reactor containing a tire sample has been determined experimentally using a GC/MS. Significant Volatile Organic Carbons (VOCs) including benzene derivatives, PAHs, and Hetero-N containing PAHs were observed. This study identifies and quantifies the concentration levels of various hazardous air pollutants, and provides new data for the overall development and validation of detailed reaction mechanisms that can describe the thermal degradation of waste tires. This information will enable the development of mitigation strategies that can address those levels of pollutant species.

KEYWORDS: Thermal degradation, Waste tire, Styrene Butadiene Rubber (SBR), Polyisoprene (IR (Natural Rubber: NR)), Waste-to-Energy, Volatile Organic Carbons (VOCs), Polycyclic Aromatic Hydrocarbons (PAHs), Hetero-N containing PAH

INTRODUCTION

A range of specialized components are used in a tire that serve to ensure the tire meets its intended design and performance requirements. Thus, direct re-use is limited without some form of chemical or thermal processing[1]. Considering a tire generation rate of 280 million per year in the U.S., waste tires can serve as a source of high quality fuel, having a high calorific value that is roughly similar to that of coal[2, 3]. However, their heterogeneity creates issues with regard to complete burnout and emissions. To accommodate these alternative feedstocks, various processes have been resurrected and modified, such as gasification and oxy-fuel combustion.

Considerable study has been done investigating the overall gasification process behavior in reactors [4-9] and studying the thermal and kinetic behavior of tire particle via the TGA tests[10-14]. Experimental work done by TGA shows much more precise and reliable data due to its ability to tightly control temperature and monitor mass change. However, the TGA test has intrinsic drawbacks due to limited heating rates, thus complimentary studies via more realistic reactor conditions need to be done. Despite this, the TGA is an excellent apparatus to understand thermal degradation and air pollutant generation mechanisms of tires due to their heterogeneous constituents; constituents like reinforcing filler, fiber, and extenders with various rubbers, such as NR, Butyl Rubber (BR), and SBR[11, 15, 16].

Previous work related to utilizing waste tires to recover energy and useful chemicals has been focused on pyrolysis/gasification and combustion at various oxygen concentrations at relatively low temperatures between 300˚C and 500˚C [17-23]. Previous work shows that most bond cleavage on monomers of main constituents is followed by hydrogenation/dehydrogenation. The substituted aromatics appear to have been formed by gas phase addition reactions and this confirmation has been carried out with structural isomers to elucidate hierarchical growing steps of substituted aromatics. Tire samples already contain a benzene ligand monomer and are a very likely precursor of PAH formation. This molecular structure likely accelerates the PAH formation during thermal conversion of tires.

To extend that understanding to a more practical level, a flow through apparatus has been used to test waste tire samples in the temperature range of