Degradation of polypropylene waste with supercritical water

Maja Čolnik[a], Petra Kotnik[a,b], Željko Knez[a], Mojca Škerget [a,*]
[a]University of Maribor, Faculty of Chemistry and Chemical Engineering, Laboratory for Separation Processes and Product Design, Smetanova 17, SI-2000 Maribor, Slovenia,
[b]University of Maribor, Faculty of Medicine, Department for Chemistry, Taborska 8, SI-2000 Maribor, Slovenia
*Corresponding author: mojca.skerget@um.si

Plastic is one of the most used materials in the world and represents the innovation of the 20th century. It is technically sophisticated, lightweight, innovative and inexpensive. Polypropylene (PP) is a hard thermoplastic polymer, and it is one of the most used plastic materials. Due to its good mechanical and physical properties (strength, low density, good tensile strength, stability in acids and bases) it has a very wide field of application. PP is used in different industry (textile, automotive, aviation, construction), for the manufacture of household appliances and for various packaging. As a result, more and more wastes are generated from PP, which accumulates in landfills, where it slowly decomposes to small molecules and thus pollutes the environment.

The use of supercritical water (SCW) for plastic processing to produce monomers or other valuable chemicals has shown many advantages over other methods in terms of efficiency, process economy and low environmental impact, especially because it is potentially useful for processing technically problematic waste such as mixed plastics and plastics contaminated with organic waste, that is otherwise incinerated. Further advantages are that the hydrolysis can be carried out quickly and selectively without a catalyst and water is easily removed from the decomposition products.

In this study SCW was used for the decomposition of PP waste. The experiments were done in a high-temperature and high-pressure batch reactor at temperatures from 425 °C to 450 °C. The mixture of water and PP waste in a ratio of 5/1 (mL/g) was exposed to reaction times from 15 min to 240 min. The resulting hydrothermal degradation products were separated into oil, gas, aqueous and solid phases, among which the oil phase was the mayor product. The chemical composition of the oil and gas phases were determined by gas chromatography/mass spectrometry (GC/MS), while the total carbon (TC) in the aqueous phase was analyzed using a TOC analyzer.

Our results indicate that the yield of gas phase increased with increasing temperature and reaction time, while the yield of oil phase decreased. Namely, high temperature and long reaction times caused, that long-chain hydrocarbons decomposed to short-chain hydrocarbons. The gas phase was mostly composed of shorter aliphatic hydrocarbons (C_1-C_6), while the oil phase contained saturated and unsaturated aliphatic hydrocarbons, alicyclic and aromatic hydrocarbons and alcohols. The concentration of total carbon in aqueous phase decreased at higher temperature and longer reaction times because the organic substances converted into the gas. Therefore, it can be concluded, that innovative SCW treatment process is suitable for chemical degradation of PP waste into valuable chemicals.