Chemical Recycling of Plastic Waste — Two Pathways for Defossilizing Chemical Industry

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Abstract

Chemical recycling of plastic waste gained increasing interest in manufacturing industries since political framework conditions and companies' self-perceptions are shifting towards more sustainable value chains. Thermochemical conversion processes, like pyrolysis of plastic containing waste, offer the potential to produce liquid products with similar properties to petroleum. Consequently, so called pyrolysis oils are suitable for the production of chemicals that are up until now derived from fossil oil. To substitute fossil oil in terms of closing carbon loops, there are two main pathways of how liquid pyrolysis products can be processed to obtain base chemicals. The first pathway, which is currently at the centre of interest, is the production of steam-cracker compatible feedstock from pyrolysis oil. In most cases this is achieved by fractional condensation or distillation of raw pyrolysis oil to generate naphtha-like liquid products. As an alternative pathway, Fraunhofer UMSICHT is investigating processes to refine pyrolysis oils to directly produce aromatic bulk chemicals from plastic wastes. This can be obtained either by pyrolysis of aromatics-based polymers as polycarbonates (e.g. from waste electrical and electronic equipment WEEE) or by the conversion of aliphatic hydrocarbons with innovative pyrolysis oil treatment techniques. Both pathways will be presented and discussed by means of one example each:

1. More than 200 kg real waste electrical and electronic equipment (WEEE) shredder residues
   were treated in a demonstration scale thermochemical conversion plant. The produced pyrolysis oil was purified and analysed. By means of fractional distillation, pure monocyclic aromatic fractions containing benzene, toluene, ethylbenzene, and xylene (BTEX aromatics) as well as styrene and α-methyl styrene were isolated for chemical recycling. Mass balances were determined and gas chromatography–mass spectrometry (GC-MS) as well as energy dispersive X-ray fluorescence (EDXRF) measurements provided data on the purity and halogen content of each fraction. This work shows that thermochemical conversion and the subsequent refining by fractional distillation is capable of recycling WEEE shredder residues, producing pure BTEX and other monocyclic aromatic fractions. A significant decrease of halogen content (up to 99%) was achieved with the applied methods.

2. The chemical recycling of roughly 3 kg of used medical face masks was demonstrated in aclosed-loop approach. The pyrolysis oil from the thermochemical conversion was upgraded by distillation to produce a steam-cracker compatible feedstock with a yield of over 37 wt%. This feedstock was added to a commercial steam-cracking process of an international petro-chemical company. By application of a mass balance approach, virgin quality polypropylene was produced and further processed to new medical face masks.