

Comprehensive characterisation of artificially aged tire wear particles by Py-GC×GC-MS

Géraldine Dumont^{1,2}, Marco Mattonai³, Jacopo La Nasa³, Milica Velimirovic², Jan Jordens², Pierre-Hugues Stefanuto¹, Jean-François Focant¹, Francesca Modugno³, Siebe Lievens^{1,4}

¹Organic and Biological Analytical Chemistry Group, MolSys Research Unit, University of Liège, 4000 Liège, Belgium

²Materials and Chemistry Unit, Flemish Institute for Technological Research (VITO), Boeretang 200, 2400 Mol, Belgium

³Department of Chemistry and Industrial Chemistry, University of Pisa, Via Moruzzi 13, 56124 Pisa, Italy

⁴Academic Center of Excellence in Separation Science and Sensing (ACESSS), University of Liège, 4000 Liège, Belgium

Plastic pollution has become an increasing environmental concern worldwide. Among the various plastic-derived materials detected in the environment, tire wear particles (TWPs) represent one of the major sources of microplastic emissions, particularly in urban and roadside environments. Once released in the environment, these particles are subjected to a range of environmental processes, including mechanical abrasion as well as physicochemical degradation induced by for instance sunlight exposure. Such processes may significantly alter the chemical composition and the properties of TWPs, yet their effects remain poorly understood. A major limitation lies in the analytical challenges associated with the complex and heterogeneous nature of these particles. In recent years, pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS) has demonstrated strong potential for the detection and characterization of TWPs through the identification of polymer-specific thermal degradation products, though limitations remain present. More recently, pyrolysis coupled to comprehensive two-dimensional gas chromatography-time of flight mass spectrometry (Py-GC×GC-ToFMS) has attracted increasing attention in this field due to its enhanced separation capacity and improved detection of complex mixtures. Despite these advantages, there is still a need for further analytical development to establish robust, sensitive and reproducible methods for the characterization of TWPs, particularly in relation to their environmental processes.

In this study, TWPs were analysed using Py-GC×GC-ToFMS, which were subjected to accelerated ageing in a solar box for periods ranging from one to four weeks, with subsamples collected weekly. The results revealed time-dependent variations in the relative abundances of characteristic pyrolysis compounds, indicating an impact of irradiation-induced degradation on TWP composition. These findings demonstrate that environmental ageing alters TWP pyrolysis fingerprints and should therefore be considered when developing reliable methods for the quantification of TWPs in environmental samples.

The authors acknowledge the COST Action ICPLASTIC CA23131 ISO compatible, efficient and reproducible protocols/equipment for mICro-nanoPLASTIC detection through machine-learning – ICPLASTIC, supported by COST (European Cooperation in Science and Technology), and the Fonds de la Recherche Scientifique (FNRS) for financial support of the current study.