

Increasing global production, the widespread use of plastic materials in all aspects of human life, and inadequate recycling are contributing to a rise in environmental plastic pollution. Plastic particles with a size of less than 5 mm are referred to as Microplastics (MPs). They are mainly formed as a result of the fragmentation of larger plastic waste under the influence of physical, chemical, and biological factors, such as UV radiation, mechanical damage, or the activity of microorganisms (secondary microplastics). They can also end up directly into the environment (primary microplastics) in the form of microbeads used in cosmetics, cleaning agents or industrial processes.

One of the primary locations where MPs accumulate is sewage sludge – a semi-solid byproduct of wastewater treatment, containing organic matter, nutrients, and chemical pollutants. It is estimated that up to 90% of the amount of MPs flowing into wastewater treatment plants, along with a sewage stream, ends up in sewage sludge after the treatment process. The most commonly detected MPs are particles of Polyethylene (PE), Polypropylene (PP), Polyethylene terephthalate (PET) and Polystyrene (PS).

Due to their small size and resistance to degradation, MPs spread easily in the environment and can bind harmful pollutants such as hydrocarbons, pesticides, heavy metals, or pharmaceuticals, posing a threat to ecosystems and human health. The direct use of sludge as a fertilizer is not permitted in the EU, as it does not meet the requirements of the EU Council Directive 86/278/EEC of 12 June 1986 due to the presence of pathogens and toxic substances. Therefore, effective methods of processing them are being sought. One promising technology is hydrothermal carbonization (HTC), which is carried out at high pressure and temperature (up to 50 bar, 160-350 °C), to dewater sludge, eliminate pathogens, and produce solid product (hydrochar) and process liquid. Unfortunately, post-HTC liquid can contain large amounts of organic and inorganic compounds, including micropollutants named Contaminants of Emerging Concern (CECs). There are, among others, phenols, Polycyclic Aromatic Hydrocarbons (PAHs) and their hydroxy derivatives (OH-PAHs), which can sorb onto the transformed MPs structure and end up in the solid product of HTC. This can lead to secondary environmental pollution with the agricultural application of biosolids. Although research indicates that HTC can effectively, partially or entirely degrade MPs, depending of process parameters, the mechanisms of these transformations and their impact on the sorption and transport of micropollutants are not sufficiently described in the literature, and it still require careful analysis.

The aim of the HTC-MPact project is to investigate the effect of hydrothermal carbonization (HTC) conditions on the physicochemical and sorption properties of microplastics (MPs) present in sewage sludge, with particular emphasis on their sorption interaction with CECs micropollutants: PAHs, OH-PAHs and phenols, therefore assessing their transport ability and the safety of land-use of HTC biosolids. The project will include international collaboration between AGH University of Krakow, Poland and University of Trento, Trento, Italy.

As part of the first part of the research, HTC processes on sewage sludge collected from Plaszow Wastewater Treatment Plant (Krakow) with the addition of polymers (PE, PP, PET, PS) will be carried out, followed by the separation and analysis of changes in morphology and chemical composition of the surface of microplastics (MPs) using microscopic and spectroscopic techniques, such as: Scanning Electron Microscopy (SEM), Fourier Transform Infrared Spectroscopy (FTIR) and Confocal Raman Microscopy (CRM).

The second part of the research will include a basic analysis of the solid product (hydrochar). It is planned to perform physicochemical analyses, including, m.in, determination of the content of carbon, hydrogen, nitrogen, phosphorus and sulphur, assessment of calorific value, and other key parameters.

In the third part of the research, the determination of targeted CECs reference values is planned, i.e., their content in raw sewage sludge, hydrochar, and post-HTC liquid, in order to establish the analytical background for the tests performed. The QuEChERS method will be used for the solid-phase extraction of PAHs and OH-PAHs. At the same time, post-HTC liquid will be tested for Total Organic Compounds (TOC), Chemical Oxygen Demand (COD), the presence of PAHs, OH-PAHs, and phenolic compounds. Spectroscopic techniques and Gas and Liquid Chromatography coupled with Mass Spectrometry (GC-MS/MS and LC-MS/MS) will be used.

Sorption experiments for given CECs will be carried out under controlled laboratory conditions, including temperature, contact time, pollutant concentration, and the amount of MPs, to determine their ability to bind selected micropollutants precisely. CECs concentrations will also be determined using chromatographic techniques. The obtained data will be used for modelling using the Freundlich isotherms, and the innovative thermodynamic modelling will be attempted.

The project will assess whether processed MPs can be a secondary source of micropollutants in the environment. The results will serve as a basis for regulations on the safe management of biosolids and reducing the presence of MPs, supporting the objectives of the EU's Circular Economy (CE) strategy and environmental protection.