

The Effect of Hydrothermal Carbonization of Sewage Sludge on Microplastic behaviour

Z. Prus¹, K. Szkadłubowicz¹, J. Mikusińska¹, X. Badura², J. Worek³, K. Kawoń⁴, M. Rugieł⁴, J. Chwiej⁴,
K. Styszko³, M. Wilk¹

¹Department of Heat Engineering & Environment Protection, Faculty of Metals Engineering and Industrial Computer Science, AGH University of Krakow, Mickiewicza 30 Ave., 30-059 Krakow, Poland

²Oil and Gas Institute – National Research Institute, Lubicz 25A Ave., 31-503 Krakow, Poland

³Department of Fuel Technology, Faculty of Energy and Fuels, AGH University of Krakow, Mickiewicza 30 Ave., 30-059 Krakow, Poland

⁴Department of Medical Physics and Biophysics, Faculty of Physics and Applied Computer Science, AGH University of Krakow, Mickiewicza 30 Ave., 30-059 Krakow, Poland

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Presenting author email: zprus@agh.edu.pl

Due to its persistence and widespread distribution, microplastic pollution is a growing environmental concern. These synthetic particles that are less than 5 mm in size can adsorb harmful chemicals and pose risks to ecosystems and public health through bioaccumulation. Wastewater treatment plants partially retain microplastics, but many accumulate in sewage sludge, often reused as agricultural biosolids (Worek et al., 2025). This raises concerns about secondary contamination, as microplastics can persist in soil and impact microbial communities, plant uptake, and water infiltration. Before reuse, advanced treatment strategies are needed to degrade or remove microplastics from biosolids. Hydrothermal Carbonization (HTC) is a promising thermochemical process that converts sewage sludge into valuable solid hydrochar while degrading pollutants (Prus et al., 2024; Xu, Z. & Bai, X., 2022). Moreover, the breakdown of plastic particles can improve potential applications of hydrochar, making it more valuable material for land and energy uses (Zhang, L. et al., 2022).

This study examines the effect of the HTC process on microplastic present in digested biosolids. Digested sewage sludge was collected from the Plaszow wastewater treatment plant in Krakow, Poland, and mixed with distilled water. HTC experiment was conducted using a 1 L steel Zipperclave Stirred Reactor equipped with a MagneDrive Agitator, supplied by Parker Autoclave Engineers, USA. Process parameters were selected as the maximum possible temperature of device (220 °C) and 4 h residence time, as longer residence time can enhance microplastic degradation, and maximum 3 h were investigated so far (Xu, Z. & Bai, X., 2022; Wang, Y. et al., 2022). The resulting hydrothermal slurry was collected. Next, it was freeze-dried to remove free water and moisture, and crushed in a mortar to homogenise. Microplastics were then extracted from 2 g of untreated biosolid and hydrochar samples by density separation using saturated CaCl₂ solution, chemically digested by 15% H₂O₂, and filtered out on GF-5 glass fibre microfilters to collect all polymer particles. Then, the samples were identified and visualized by microscopic and spectroscopic analyses to evaluate the impact of hydrothermal carbonization process on microplastic behaviour (Figure 1).

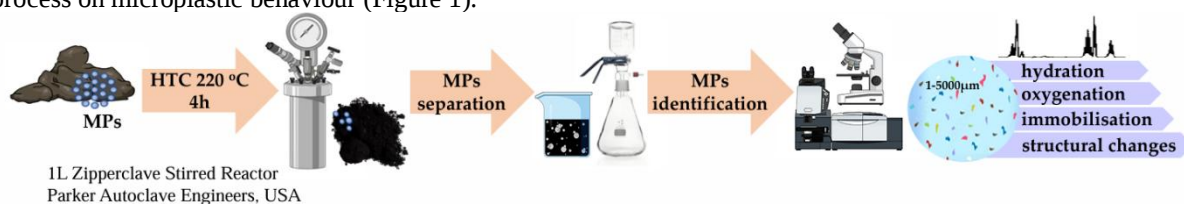


Figure 1. The methodology used for the study

Consequently, Raman microspectroscopy (WiTec Alpha 300 R confocal microscope with 532 nm excitation laser beam and UHRS 300 spectrometer) and Fourier-transform infrared spectroscopy (FTIR) technique (Bruker 400 FTIR-ATR spectrometer) were used to observe size differences and evaluate particle degradation, identifying oxygen-containing functional groups and changes in aromatic structures.

Furthermore, microscope observation of a randomly selected 10 mg subsample under a 10× air lens confirmed that post-HTC microplastic particles are smaller and more widely distributed across the field (Fig. 2). Moreover, they are more brittle, as evidenced by the reduction in laser energy required for collecting Raman spectra. FTIR-ATR analysis has shown that hydration and oxygenation in the structure occurred (Fig. 3), which contributes to particle destabilisation.

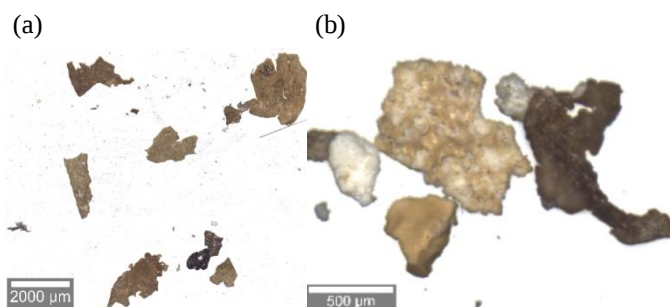


Fig. 2. Observed microplastic separated from digested sewage sludge (a) and hydrochar (b).

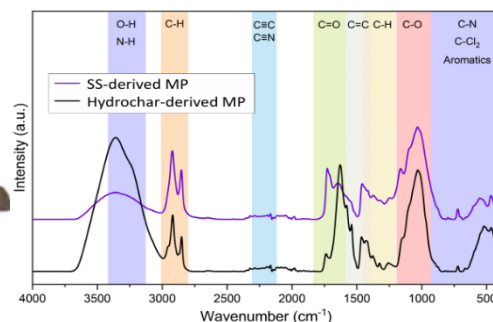


Fig. 3. FTIR spectra for separated microplastic

These findings have expanded the understanding of the fate of microplastic transformations during the HTC of sewage sludge. The research demonstrates that the HTC method can alter the chemical and structural properties of microplastics in biosolids, making them more fragile and susceptible to further degradation, decreasing the risk of secondary contamination from agricultural and land use of biosolids. Microscopic and spectroscopic analyses confirmed that particle sizes have been reduced with increased brittleness.

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