Fate and behaviour of microplastics during hydrothermal carbonization of sewage sludge

Małgorzata Wilk[1, *], Zuzanna Prus[1], Wojciech Strojny [2], Klaudia Szkadłubowicz[1], Joanna Mikusińska[1], Katarzyna Styszko[1], Renata Gruca-Rokosz[2]

[1]AGH University of Krakow, al. A. Mickiewicza 30, 30-059 Kraków, Poland
[2]Rzeszow University of Technology, Al. Powstańców Warszawy 12, 35-959 Rzeszów, Poland

*Corresponding author: ***mwilk@agh.edu.pl***

Abstract

This study evaluated the effect of hydrothermal carbonization (HTC) on microplastics in anaerobically digested sewage sludge. Microplastics were extracted from biosolids and hydrochar and analyzed using LDIR spectroscopy. The results demonstrate the applicability of LDIR to highly carbonized matrices and indicate a reduction of microplastics during hydrothermal carbonization.

Methodology

- HTC process conditions: 220 °C, 4 h.
- MPs isolated by chemical digestion, density separation and vacuum filtration
- MPs identified by Laser Direct Infrared imaging (LDIR) at a range 30-5000 µm

Results

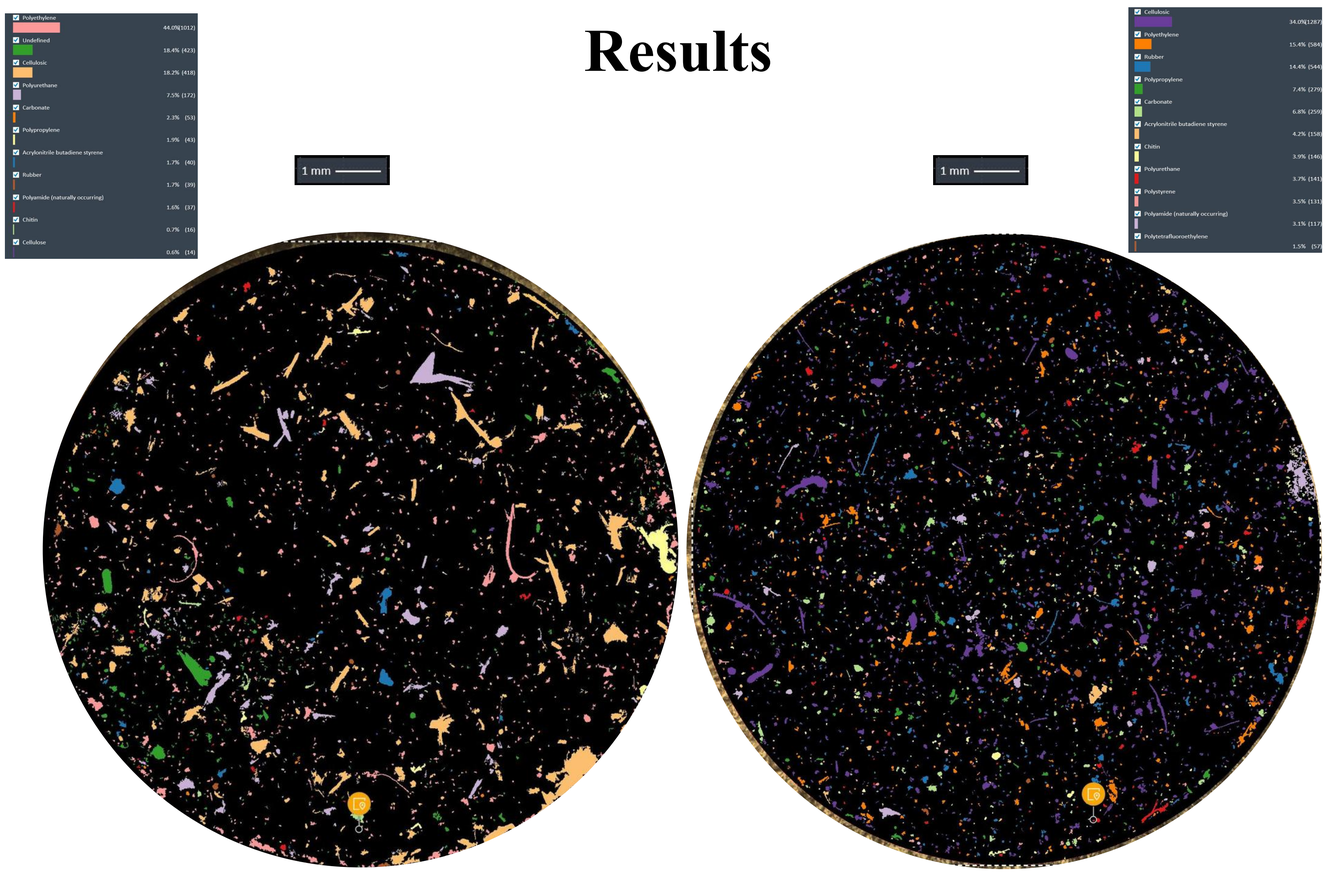

Figure 1. LDIR images of particle distribution extracted from a) 0.1 g of sewage sludge, and b) 0.2 g of hydrochar.

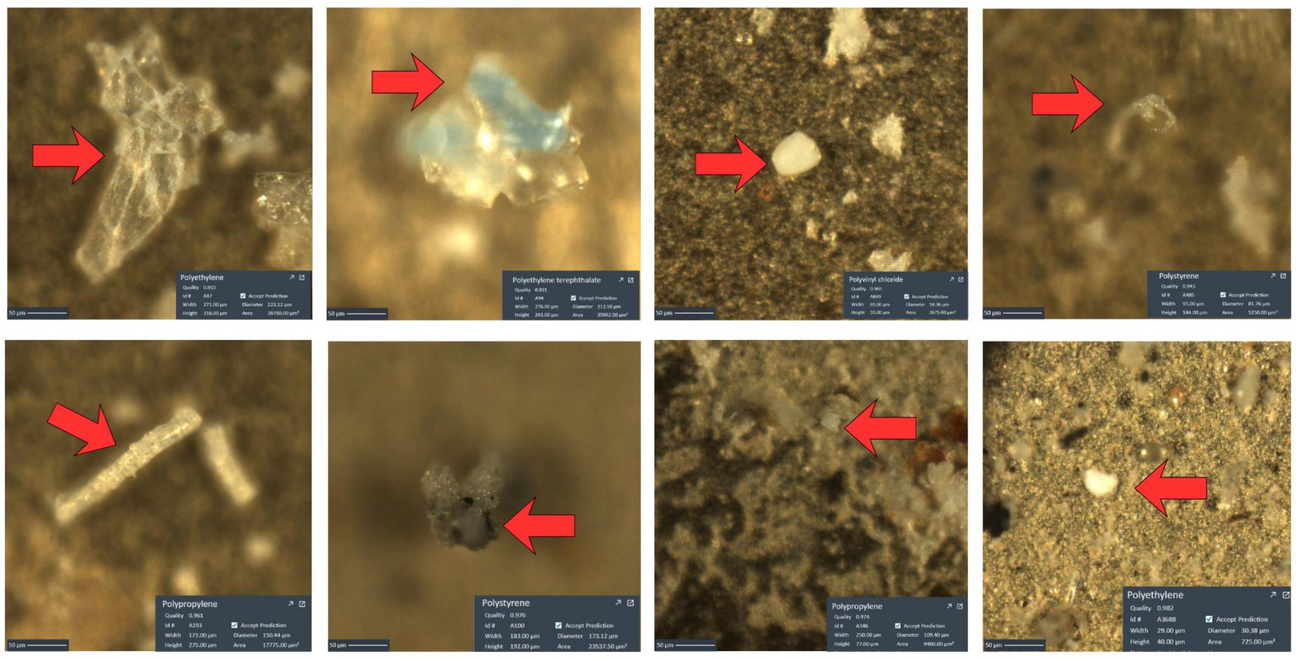

Figure. 2. Microscopic images of selected MPs captured from a-e) sewage sludge, and f-h) hydrochar.

Table 1. Abundance (number of particles), cumulative surface area, and RS contribution of particles detected in sewage sludge and hydrochar samples using LDIR chemical imaging.

	Sewage sludge*			Hydrochar		
Particle type	Number of particles	Cumulative surface area (µm²)	RS (%)	Number of particles	Cumulative surface area (µm²)	RS (%)
Total particles	2990	2.70×10^7		1580	6.6×10^6	
			to total particles			*to total particles*
Total MPs	2298	1.28×10^7	47.57	1031	4.2×10^6	63.45
Carbonates & sand	16	3.63×10^4	0.13	24	1.2×10^5	1.81
Cellulose	628	1.39×10^7	51.31	476	2.1×10^6	31.85
Chitin + PA	48	2.63×10^5	0.97	49	1.9×10^5	2.90
			to total MPs			*to total MPs*
PU	272	4.09×10^6	31.84	97	4.6×10^5	11.00
ABS	42	3.07×10^5	2.39	101	4.0×10^5	9.49
PP	74	5.20×10^5	4.05	270	1.0×10^6	24.93
PE	1846	7.22×10^6	56.22	435	1.9×10^6	44.99
PET	10	1.71×10^5	1.33	0	0.0	0.00
PS	4	1.24×10^4	0.10	126	4.0×10^5	9.53
PVC	8	3.23×10^5	2.51	0	0.0	0.00
PMMA	8	5.29×10^4	0.41	2	2.2×10^3	0.05
Rubber	34	1.48×10^5	1.15	0	0.0	0.00

RS - Relative surface area shares determined by relating the cumulative surface area of particles within each size class to the total cumulative surface area of detected MPs in the respective sample, %

**Results for sewage sludge normalised from 0.1 g to 0.2 g of mass.*

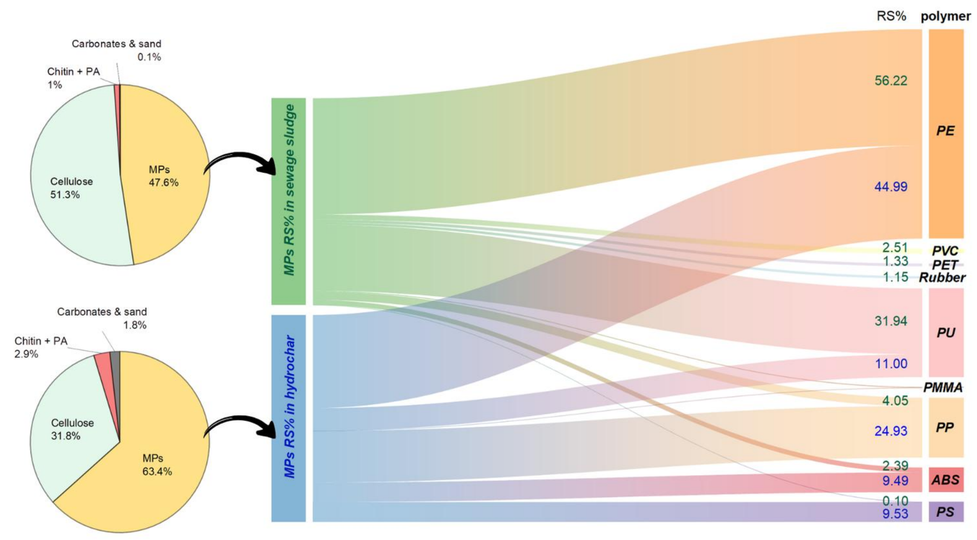

Figure. 3. Graphical interpretation of particle shares and MPs composition of a) sewage sludge, and b) hydrochar.

Table 2. Removal efficiency of individual polymer types

Polymer	Sewage sludge (particles)	Hydrochar (particles)	PNR (%)	Area in sewage sludge (µm²)	Area in hydrochar (µm²)	CSAR (%)
PU	272	97	64.3	4.09×10^6	4.6×10^5	88.7
ABS	42	101	−140.5	3.07×10^5	4.0×10^5	−30.3
PP	74	270	−264.9	5.20×10^5	1.0×10^6	−92.3
PE	1846	435	76.4	7.22×10^6	1.9×10^6	73.7
PET	10	0	100	1.71×10^5	0	100
PS	4	126	−3050	1.24×10^4	4.0×10^5	−3125
PVC	8	0	100	3.23×10^5	0	100
PMMA	8	2	75.0	5.29×10^4	2.2×10^3	95.8
Rubber	34	0	100	1.48×10^5	0	100

***PNR (%)** – particle number removal, calculated based on the reduction in the number of MPs between sewage sludge and hydrochar; **CSAR (%)** – cumulative surface area removal, calculated based on the reduction in the cumulative surface area of MPs between sewage sludge and hydrochar.*

Conclusions

HTC:

- reduced MP abundance by ~55% and cumulative surface area by ~67%
- changed MP size distribution and polymer composition
- PET, PVC, and rubber were not detected in hydrochar, while more stable polymers remained present.
- shows potential for reducing MP contamination in sewage sludge.

Acknowledgements

This research was partially funded by the National Science Centre, Poland, under project no. 2024/55/B/ST8/01847. The project was also supported by the by the Ministry of Science and Higher Education of Poland [AGH grant no. 16.16.110.663/501.00-110000-10000] and by the program "Excellence initiative—research university" for the AGH University of Krakow, Poland. The authors gratefully acknowledge EKOPROD Ltd. as the proprietor of the HTC apparatus.