Options for riverine plastic waste collected in Motława river (Poland)

Kacper Pobłocki, Emilia Gonatrek-Castro, Onur Cavdar, Patrycja Jutrzenka Trzebiatowska

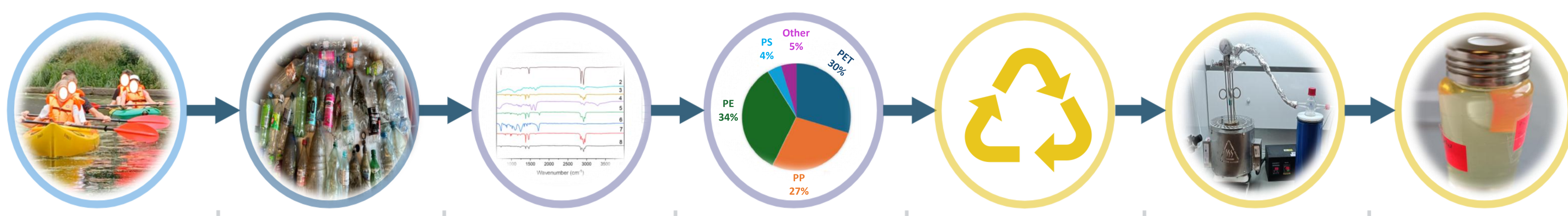
Department of Environmental Technology, Faculty of Chemistry, University of Gdansk, Wita Stwosza 63, 80-308 Gdansk, Poland

E-mail: kacper.poblocki@phdstud.ug.edu.pl

Introduction

Marine plastic pollution is a growing environmental challenge, with approximately 80% of plastic entering seas and oceans originating from land-based sources and being transported through rivers, canals, and harbours. Continuous fragmentation of larger plastic debris generates microplastics, creating long-term ecological risks and highlighting the need for effective waste management strategies across the entire plastic lifecycle. Mechanical recycling remains the most common treatment route; however, its efficiency decreases for contaminated and degraded waste streams. In such cases, advanced approaches such as solvent-based purification and chemical recycling provide promising alternatives for converting plastic waste into valuable products and secondary raw materials. Within the Circular Ocean Plastic (COP) project, riverine plastic waste collected in Gdańsk was investigated as a potential feedstock for recycling processes. Solvent-based recycling of polyolefins (PP and HDPE) and chemical recycling of PET waste were explored to evaluate their potential for plastic valorization and circular economy applications.

Waste collection | **Waste sorting** | **Plastic identification** | **Plastic valorization**



"Ekokajak" initiative
Plastic waste was collected from the Motława River during the "Ekokajak" initiative and presorted before further analysis.

Waste preprocessing
Collected plastic waste was washed, separated, and categorized according to material type and intended use prior to further analysis

Plastic characterization
Plastic samples were identified using FTIR and TGA analyses to determine polymer composition and material properties.

Waste composition
The proportion of different plastic fractions was determined based on weight and quantity analysis.

Recycling pathway selection
Suitable recycling methods were selected based on the identified polymer types.

Chemical recycling or pyrolysis
Plastic fractions were processed using glycolysis or pyrolysis techniques.

Product recovery
Recovered products included liquid, gaseous, and solid fractions for further evaluation (TGA, FTIR, GC-MS, NMR, GPC)

Figure 1. Workflow of plastic waste collection, characterization, and valorization within the Circular Ocean Plastic (COP) project, including waste collection, polymer identification, composition analysis, and selection of chemical recycling pathways.

OBP Waste fraction

Plastic fraction	Pieces	Amount (%)
Bottles	**54**	**25.12**
Bottle caps	**45**	**20.93**
Bottle labels	**29**	**13.49**
Food product cups/lids	7	3.26
Small containers	10	4.65
Polystyrene foam	8	3.72
Fishing gear	1	0,46
Pieces of plastic foil	5	2.32
Grocery/Shopping bags	22	10.23
Food product wrappers/packaging	**32**	**14.88**
Nitrile glove	1	0.46
Balloon	1	0.46
Sum	**215**	**100**

*Based on the 4-week collection July-August 2025

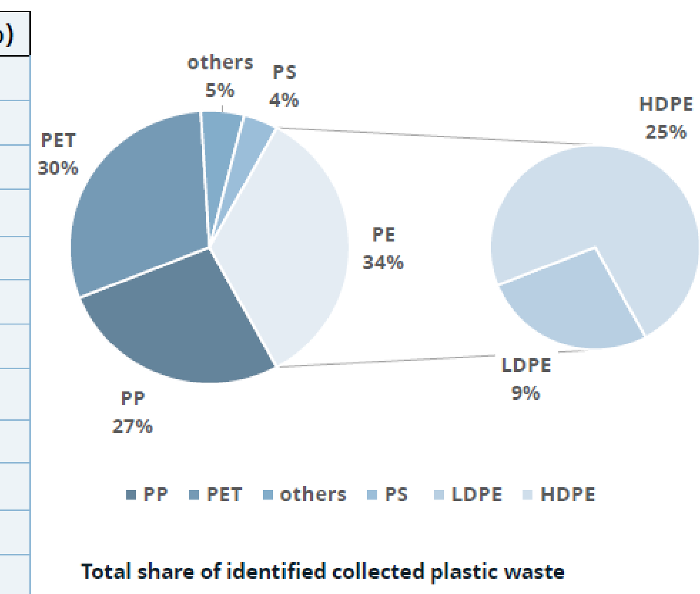
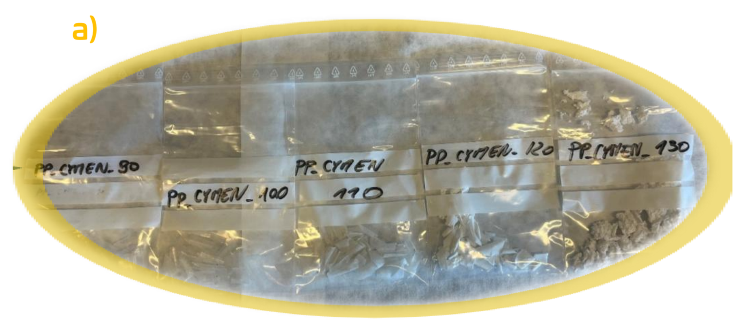


Figure 2. Composition and distribution of collected ocean-bound plastic (OBP) waste fractions from the Motława River.

Chemical recycling

PP Solvent-based recycling

a)



Marine-derived PP is highly contaminated and often degraded, limiting the efficiency of conventional mechanical recycling. Solvent-based recycling offers a promising route for selective polymer purification and recovery. In this study, cymene was investigated as a greener alternative to xylene due to its similar affinity toward PP. Optimal dissolution conditions were evaluated to maximize polymer recovery while minimizing degradation.

b) c) d)

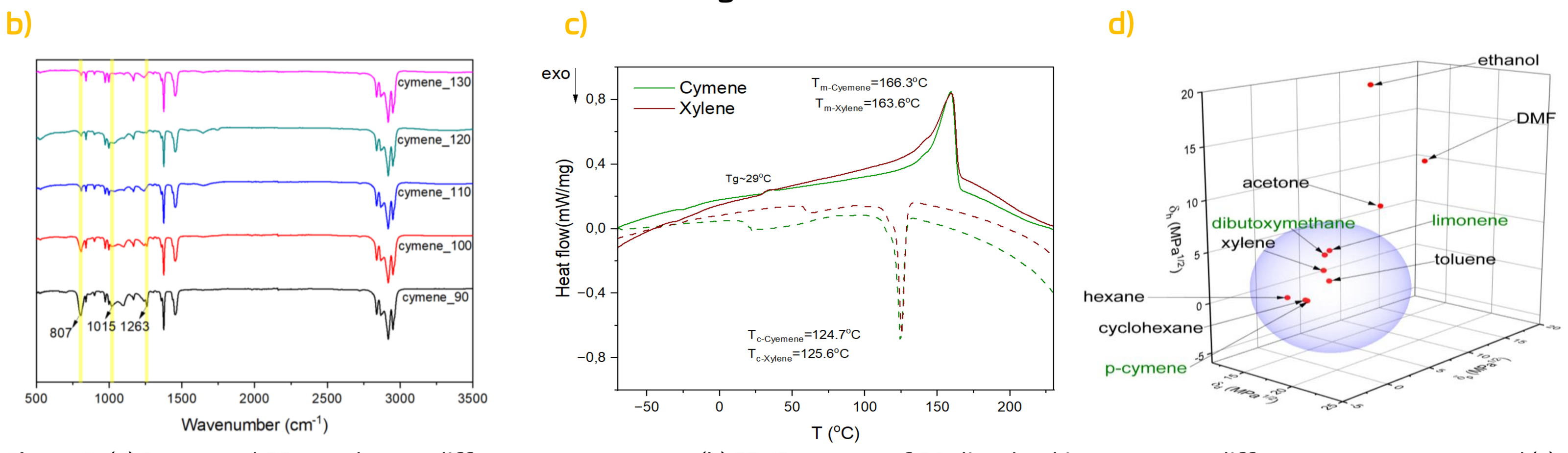


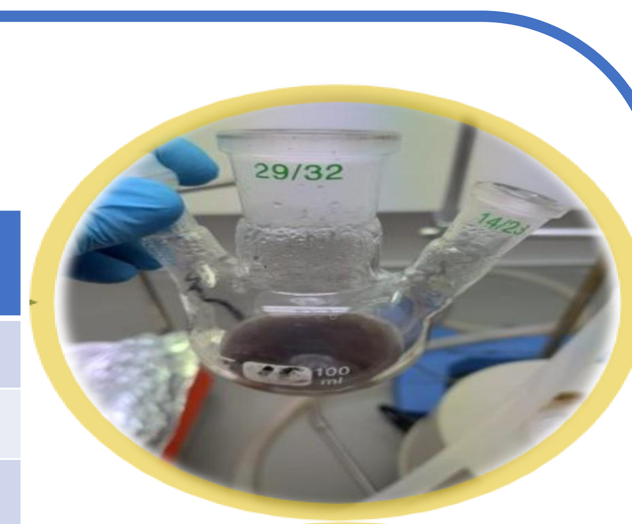
Figure 3. (a) Recovered PP powders at different temperatures (b) FT-IR spectra of PP dissolved in cymene at different temperatures and (c) DSC curves of PP dissolved in cyemene and xylene at 130°C. (d) Hansen solubility parameter sphere model for PP.

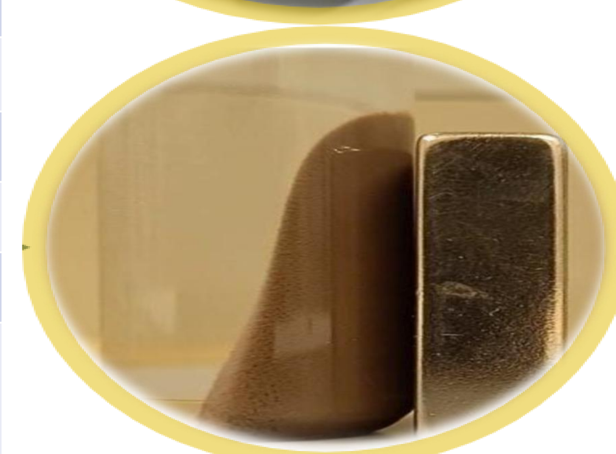
PET glycolysis

Table 1. Effect of catalyst composition and reaction parameters on PET glycolysis and BHET yield.

Catalyst	EG:PET (mol/mol)	PET/M (mol/mol)	BHET yield (%) [a]
$Zn(OAc)_2$	14.78	111.75	49.87
	22.46	111.42	65.89
	31.36	108.63	51.76
	63.14	105.84	48.56
	24.17	**114.43**	**76.88**
$ZnFe_2O_4$(ZFO)	24.01	105.83	70.85
$CoFe_2O_4$(CFO)	24.07	106.36	60.71
CFO/ZSM-5 (75/25)	24.08	113.5	69.12

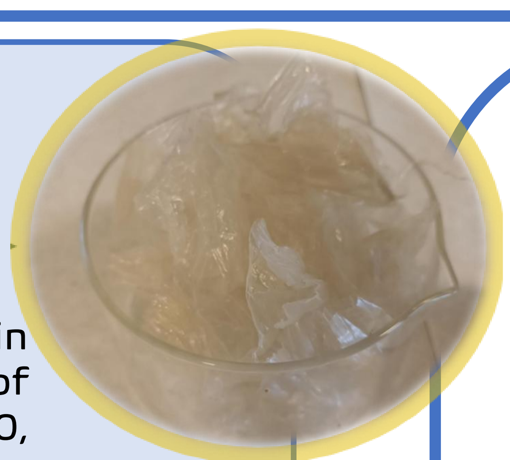
a) based on ^1H NMR studies. Temperature = 197-200°C , time = 90 min.





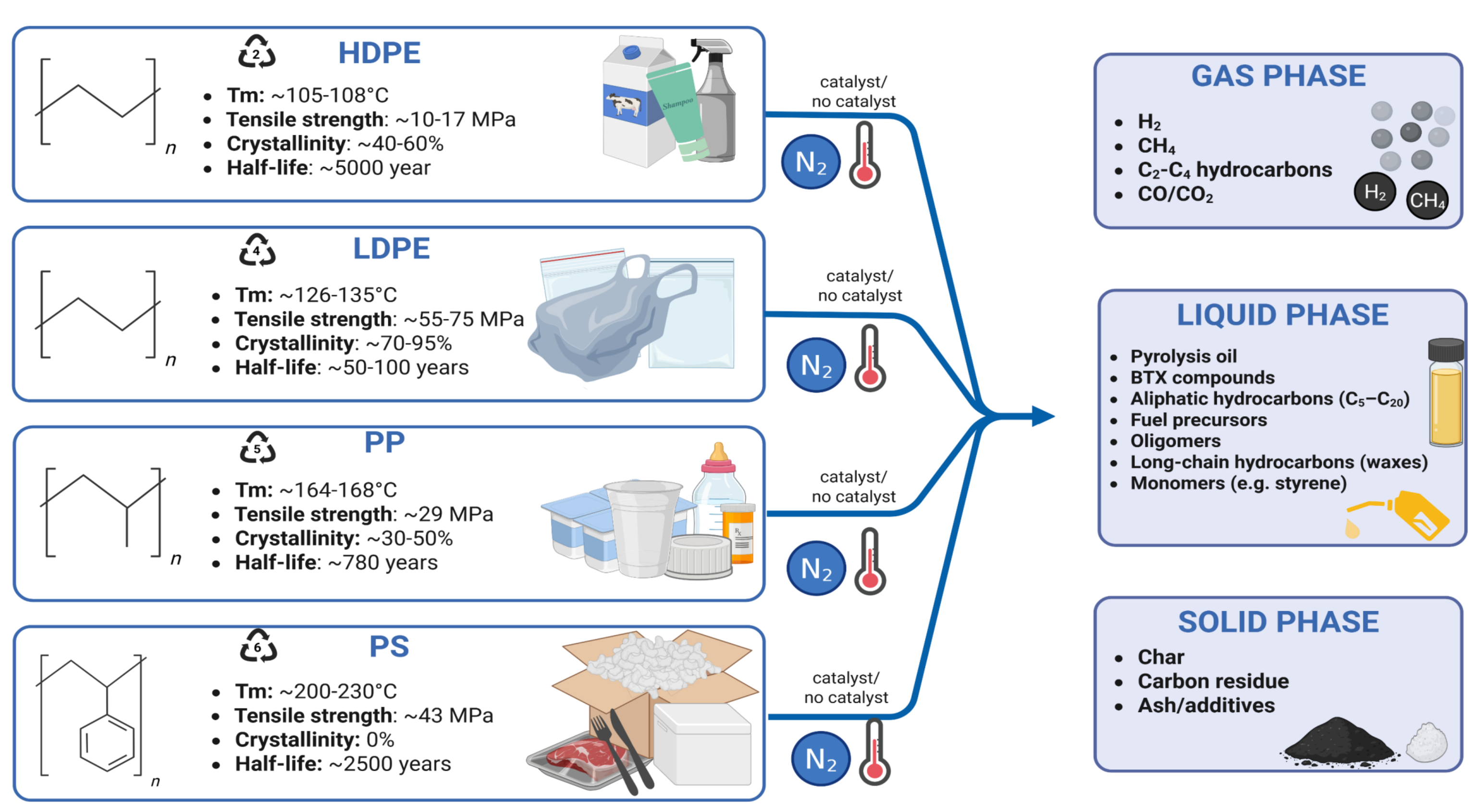
Magnetically recoverable catalyst

PP solvent-based recycling



PP was dissolved in cymene up to a level of 15 wt.% at 90, 100, 110, 120 and 130°C under stirring at 300 rpm. The hot solution (40 mL) was poured into 160 mL of antisolvent (ethanol) and the system was kept at room temperature overnight, resulting in recovered polymer powders. The obtained powders have been characterized by FTIR-ATR and DSC analyses.

Pyrolysis



PET glycolysis

Collected PET waste bottles was sorted, washed, and mechanically pretreated prior to glycolysis. Depolymerization was carried out in a round-bottom flask using ethylene glycol and selected catalysts at 197–200°C for 90 min. The reaction products were purified by filtration and crystallization to isolate BHET, and product yields were determined by ^1H NMR.

Conclusion

- During the *"Ekokajak"* initiative, the collected riverine plastic waste stream was predominantly composed of polyethylene (PE, 34%; including HDPE – 73% and LDPE – 27%), polyethylene terephthalate (PET, 30%), and polypropylene (PP, 27%), indicating a predominantly packaging- and food-related origin.
- The combined use of visual identification (RIC), FTIR spectroscopy, and TGA analysis enabled reliable polymer classification and supported the selection of appropriate recycling strategies.
- Solvent-based purification using environmentally friendly solvents demonstrated potential for the recovery of contaminated polyolefin fractions while preserving polymer properties.
- Chemical depolymerization of PET *via* glycolysis resulted in efficient BHET production, reaching yields up to 76.9% depending on catalyst composition and reaction conditions.

Acknowledgment

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COP Circular Ocean-bound Plastic | Interreg South Baltic | Co-funded by the European Union | IN MARI VIA TUA | University of Gdańsk | Fahrenheit Universities | CHEMIA UG | Department of Environmental Technology