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# Including impacts from littering in LCA: a case study of disposable plastic cups

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# Agenda

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- Introduction & Research goal
- Methodology
- Results
- Conclusion
- Next steps

# Introduction

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- Globally, ~ 500 billion disposable cups are consumed each year [\[Lewis et al. 2021\]](#)
- Existing LCAs of products made of PP or PLA fail to address the impacts of littering and the toxicity of leachates
- Available impact assessment methodologies do not allow a full assessment of the impacts of plastic emissions
- **Aim:** Comparative cradle-to-grave LCA of disposable plastic cups made of PP and PLA
  - Including toxicity of leachates
  - Including impacts related to the littering of the cups

# Methodology

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- Product Environmental Footprint (PEF)
- Persistence-based plastic pollution equivalents as a proxy for impacts [\[Maga et al. 2022\]](#)
  - Redistribution
  - Degradation
- Degradation rates extracted from experiments measuring CO<sub>2</sub> production / mass loss
- New impact category: plastic pollution
- Integration into the PEF by normalization based on [\[Galafton et al. 2023\]](#) and weighting with the highest / lowest weighting factor recommended by the [\[Joint Research Centre 2018\]](#)
- Alternatively: include in safe-and-sustainable-by-design (SSbD) assessment [\[Caldeira et al. 2023\]](#)

# Methodology: Case study

- Case study: disposable cups made of PP / PLA
- FU = 1 transparent disposable plastic cup for cold drinks with a filling volume of 500 mL

Material:	Polylactic Acid	Polypropylene
Weight:	11.3675 g	8.3423 g
Volume	500 ml	
Wall thickness	150 $\mu$ m	
Length	16 cm	
Top Diameter	9.0 cm	
Bottom Diameter	5.8 cm	



- Cradle-to-grave with two EoL scenarios: thermal treatment, recycling
- Direct plastic emissions (littering)  $\rightarrow$  2 % [\[Jambeck et al. 2015\]](#)
- Degradation rates based on accelerated weathering experiment (1544 h;  $\sim$ 1 y 2 m 11 d real life)

# Results: degradation experiment

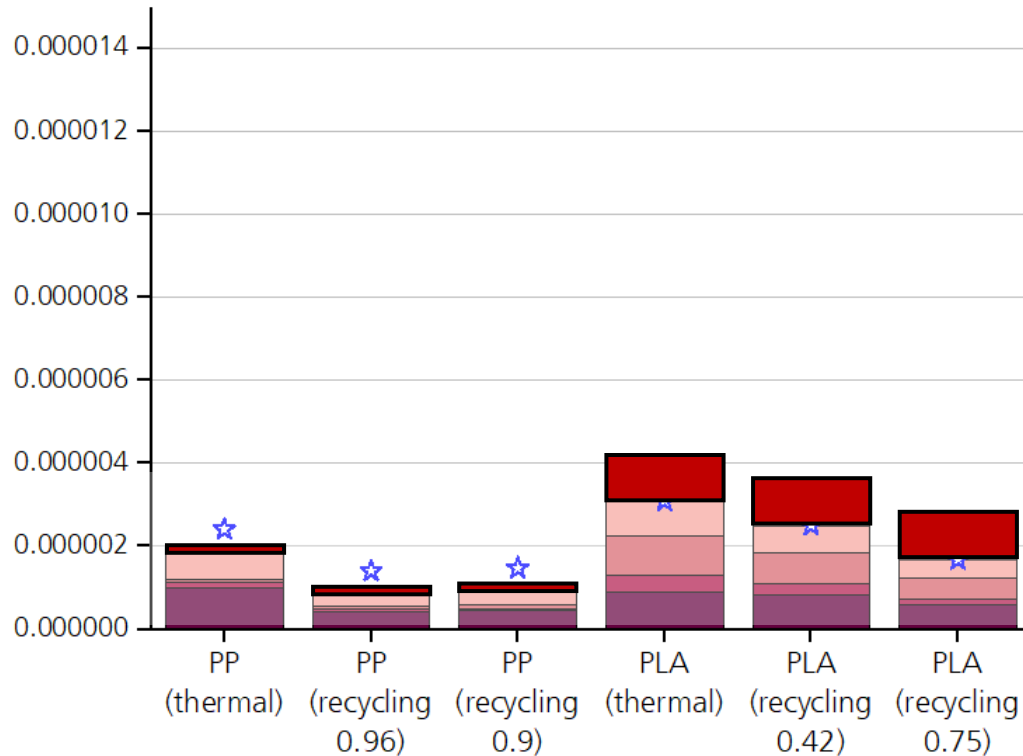
Specific surface degradation rates used to calculate fate factors [in  $\mu\text{m}/\text{year}$ ]



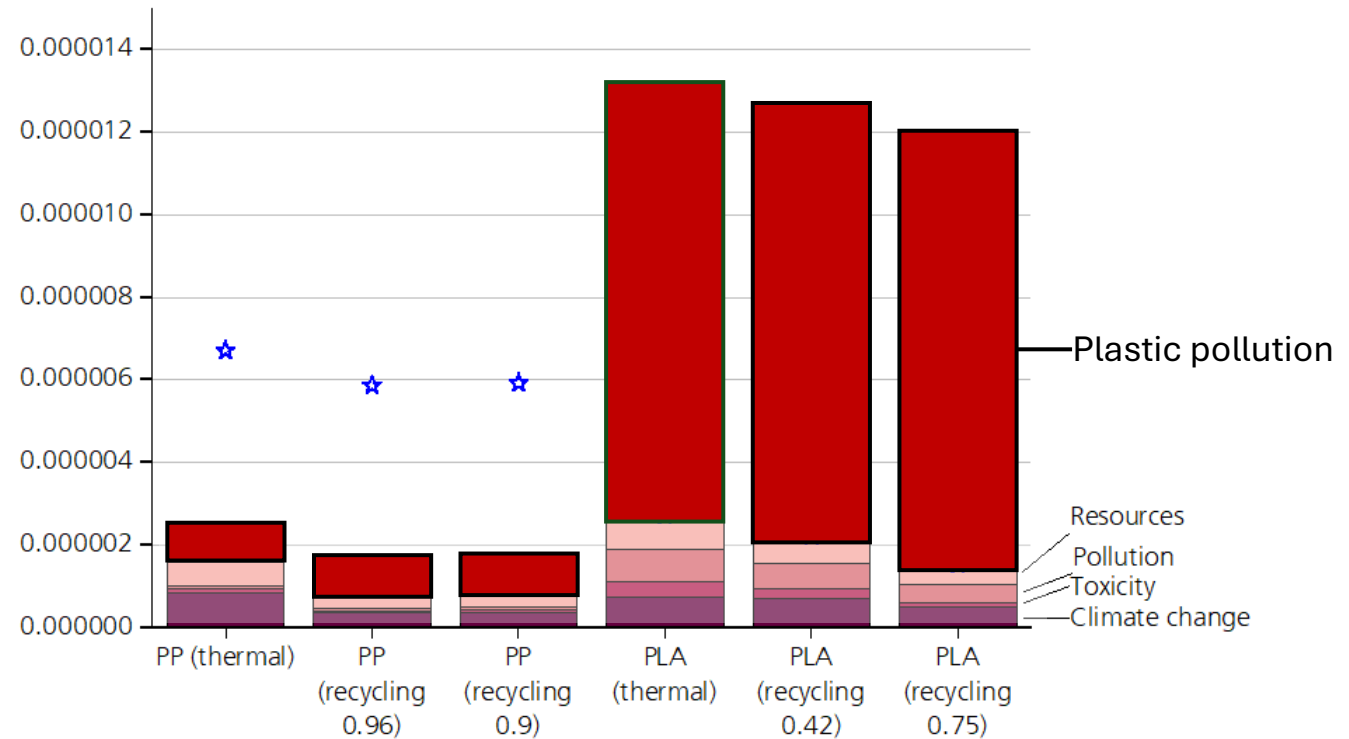
Environmental compartment	Terrestrial (buried)	Terrestrial (surface)	River sediment	Marine water	Marine sediment
PP	1.330 (0.884 – 4.671)	7.016	n.a.	2.537 (0.198 – 7.604)	n.a.
PLA	57.031 (0-186.224)	0.877	0.001	n.a.	0.001

# Results: normalized, weighted

Total impacts ([-]/FU, low WF for plastic pollution)



Total impacts ([-]/FU, high WF for plastic pollution)



WF = weighting factor

★ Total impacts with degradation rates based on literature

# Results: SSbD scores

## Comparing the investigated alternative (PLA) to the base case (PP)

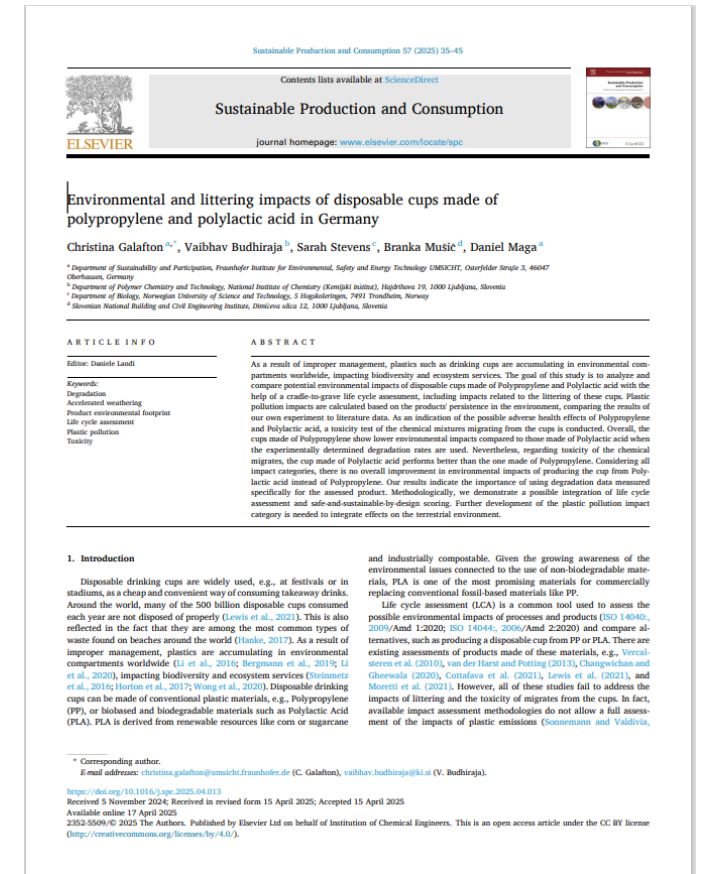
Group	Impact category	Thermal treatment			Recycling <sub>economic</sub>			Recycling <sub>default</sub>		
		Change [%]	Score	Score	Rel. change	Score	Score	Rel. change	Score	Score
Climate change	Climate change	11	2	2	-93	0	0	-30	0	0
Pollution	Acidification	-953	0	0	-717	0	0	-432	0	0
	Eutrophication, freshwater	-12 467	0		-1 507	0		-700	0	
	Eutrophication, marine	-1 961	0		-1 040	0		-568	0	
	Eutrophication, terrestrial	-846	0		-616	0		-381	0	
	Ionizing radiation	-308	0		-94	0		-54	0	
	Ozone depletion	-636 941	0		-179 530	0		-8 3194	0	
	Particulate matter	-1 317	0		-1 103	0		-704	0	
	Photochemical ozone formation	-470	0		-538	0		-321	0	
	<b>Plastic pollution</b>	-991	0		-991	0		-991	0	
Toxicity	Ecotoxicity, freshwater	-279	0	1.4	-554	0	1.2	-204	0	1.2
	<b>Ecotoxicity of the chemical leachates</b>	478	3		478	3		478	3	
	Human toxicity, cancer	-623	0		-748	0		-309	0	
	Human toxicity, non-cancer	-8	1		-122	0		-20	0	
	<b>Human toxicity of the chemical leachates</b>	1 103	3		1 103	3		1 103	3	
Resources	Land Use	-5 536	0	0.5	-841	0	0	-409	0	0.3
	Resource use, fossils	12	2		-75	0		-9	1	
	Resource use, mineral and metals	-1316	0		-643	0		-296	0	
	Water use	-705	0		-1 465	0		-653	0	
<b>Total</b>				<b>1.0</b>			<b>0.3</b>			<b>0.4</b>

no improvement (-10–+5%)

deterioration (up to -10%)

# Conclusions

- Conventional environmental impacts: PP cup < PLA cup
- Plastic pollution: PP cup < PLA cup
- Toxicity of leachates: PP cup > PLA cup
  
- PLA cup shows no environmental advantages compared to the PP cup
- Important to use product-specific degradation data when assessing plastic pollution impacts
- Simulating and measuring degradation is complex



<https://doi.org/10.1016/j.spc.2025.04.013>

# Next steps

- Integrate effect factors [7,8,9,10,11] into the methodology
- Determine effects of polymer types, sizes, and shapes of emissions on effects
- Develop a methodology to estimate and incorporate impacts of additives



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# References

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1. Lewis, Y.; Gower, A.; Notten, P. Single-use beverage cups and their alternatives: Recommendations from Life Cycle Assessments, 2021. Available online: [https://www.lifecycleinitiative.org/wp-content/uploads/2021/03/UNEP-D002-Beverage-Cups-Report\\_lowres.pdf](https://www.lifecycleinitiative.org/wp-content/uploads/2021/03/UNEP-D002-Beverage-Cups-Report_lowres.pdf).
2. Maga, D.; Galafton, C.; Blömer, J.; Thonemann, N.; Özdamar, A.; Bertling, J. Methodology to address potential impacts of plastic emissions in life cycle assessment. *Int J Life Cycle Assess* 2022, 469–491.
3. Galafton, C.; Maga, D.; Sonnemann, G.; Thonemann, N. Life cycle assessment of different strawberry production methods in Germany with a particular focus on plastic emissions. *Int J Life Cycle Assess* 2023, 611–625.
4. Joint Research Centre of the European Commission. Development of a weighting approach for the Environmental Footprint EUR 28562 EN, 2018. Available online: <https://eplca.jrc.ec.europa.eu/LCDN/developerEF.html>.
5. Caldeira, C.; Farcas, R.; Moretti, C.; Mancini, L.; Rauscher, H.; Riego Sintes, J.; Sala, S.; Rasmussen, K. Safe and sustainable by design chemicals and materials – Review of safety and sustainability dimensions, aspects, methods, indicators, and tools, 2023.
6. Jambeck, J.R.; Geyer, R.; Wilcox, C. Plastic waste inputs from land into the Ocean. *Science* 2015, 347, 764–768, doi:10.1126/science.1260879.
7. Lavoie, J.; Boulay, A.-M.; Bulle, C. Aquatic micro- and nano-plastics in life cycle assessment: Development of an effect factor for the quantification of their physical impact on biota. *J Ind Ecol* 2021, doi:10.1111/jiec.13140.
8. Corella-Puertas, Elena; Hajjar, Carla; Lavoie, Jérôme; Boulay, Anne-Marie (2023): MarILCA characterization factors for microplastic impacts in life cycle assessment: Physical effects on biota from emissions to aquatic environments. In: *J Cleaner Prod* 418, S. 138197. DOI: 10.1016/j.jclepro.2023.138197.
9. Saadi, N.; Lavoie, J.; Fantke, P.; Redondo-Hasselerharm, P.; Boulay, A.-M. Including impacts of microplastics in marine water and sediments in life cycle assessment. *Journal of Cleaner Production* 2025, 520, 146037, doi:10.1016/j.jclepro.2025.146037.
10. Tunali, Merve; Nowack, Bernd (2025): Towards including soil ecotoxicity of microplastics and tire wear particles into life cycle assessment. In: *Ecotoxicology and Environmental Safety* 303, S. 118856. DOI: 10.1016/j.ecoenv.2025.118856.
11. Vázquez-Vázquez, Brais; Lazzari, Massimo; Hospido, Almudena (2025): Terrestrial characterization factors for bio- and fossil-based plastics: microplastics ingestion and additives release. In: *Waste Management* 196, S. 106–114. DOI: 10.1016/j.wasman.2025.02.008.

Overall approach and results: Galafton, C.; Budhiraja, V.; Stevens, S.; Mušič, B.; Maga, D. Environmental and littering impacts of disposable cups made of polypropylene and polylactic acid in Germany. *Sustainable Production and Consumption* 2025, 57, 35–45, doi:10.1016/j.spc.2025.04.013.

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