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Reconciling plastic release: Modelling of macro and microplastic flows to the environment

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The modeling approach

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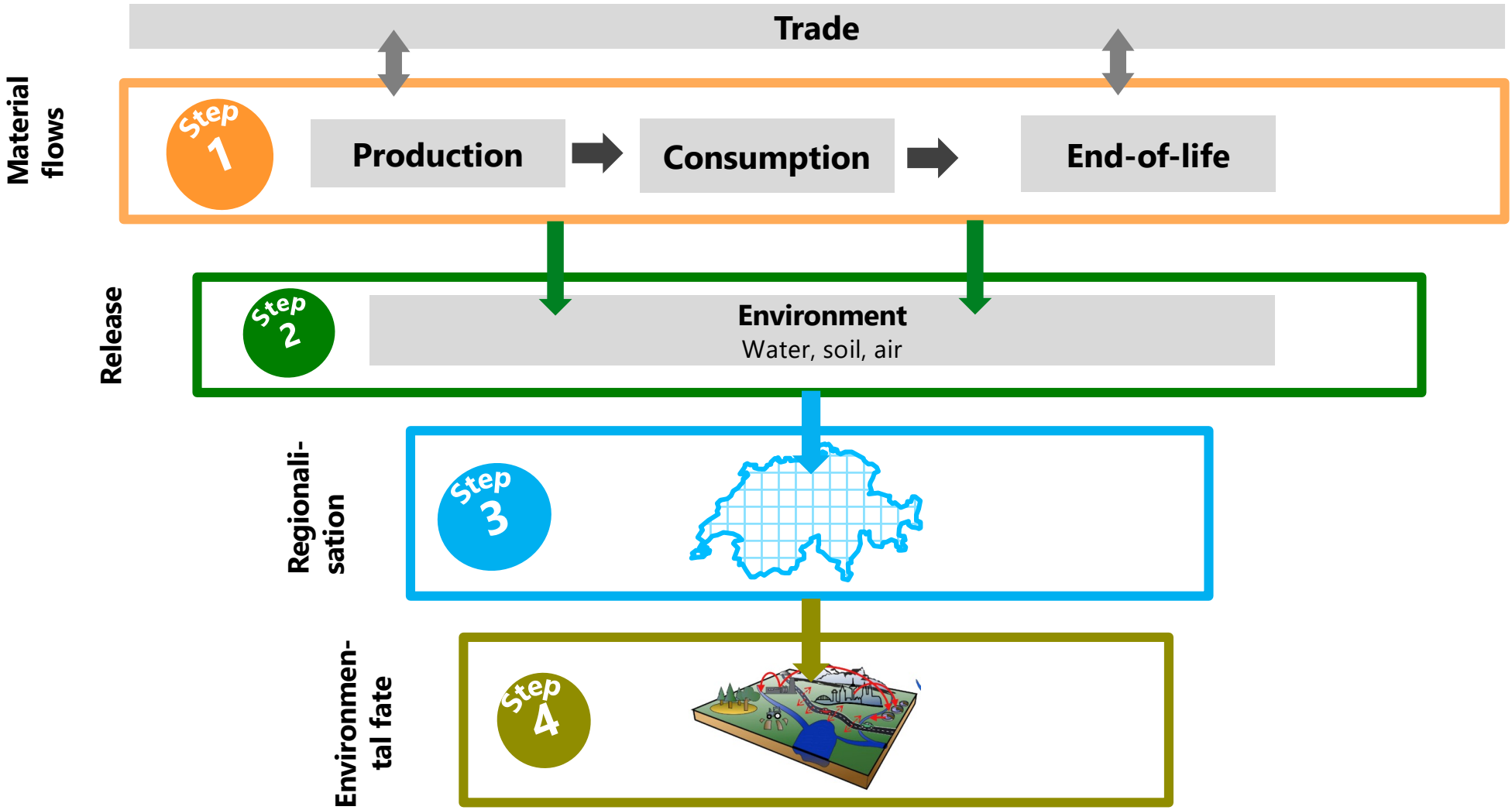

Material flow analysis

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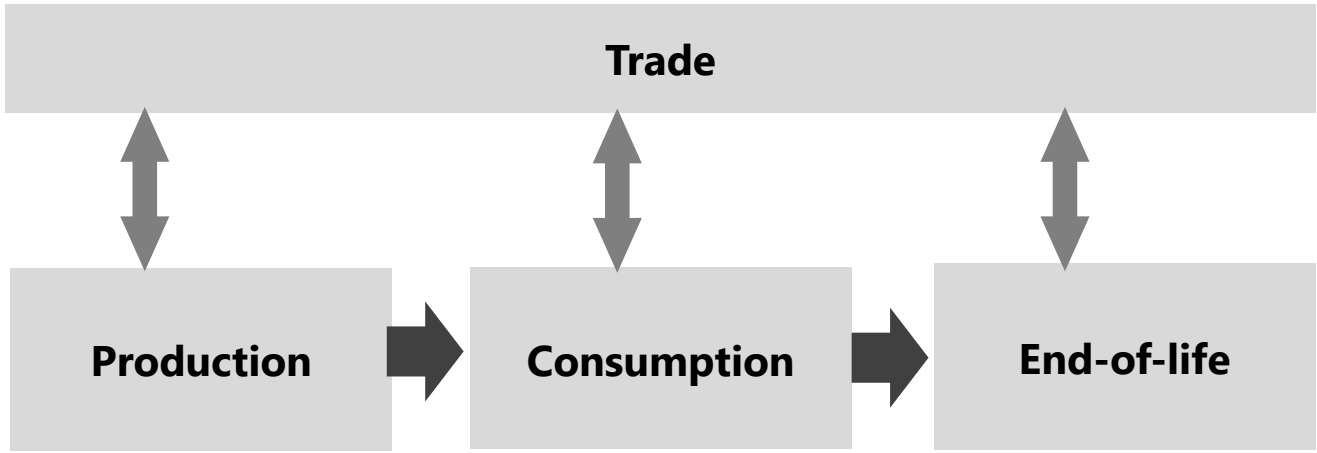

- Considered polymers: LDPE, HDPE, PP, PS, EPS, PVC, PET, PUR, PMMA, ABS, PA, PC, tires
- Regions: EU, Switzerland, China, Japan
- 9 product sectors, 40 product categories, 11 waste collection systems
- 245 emission flows

Peak Plastic in Switzerland

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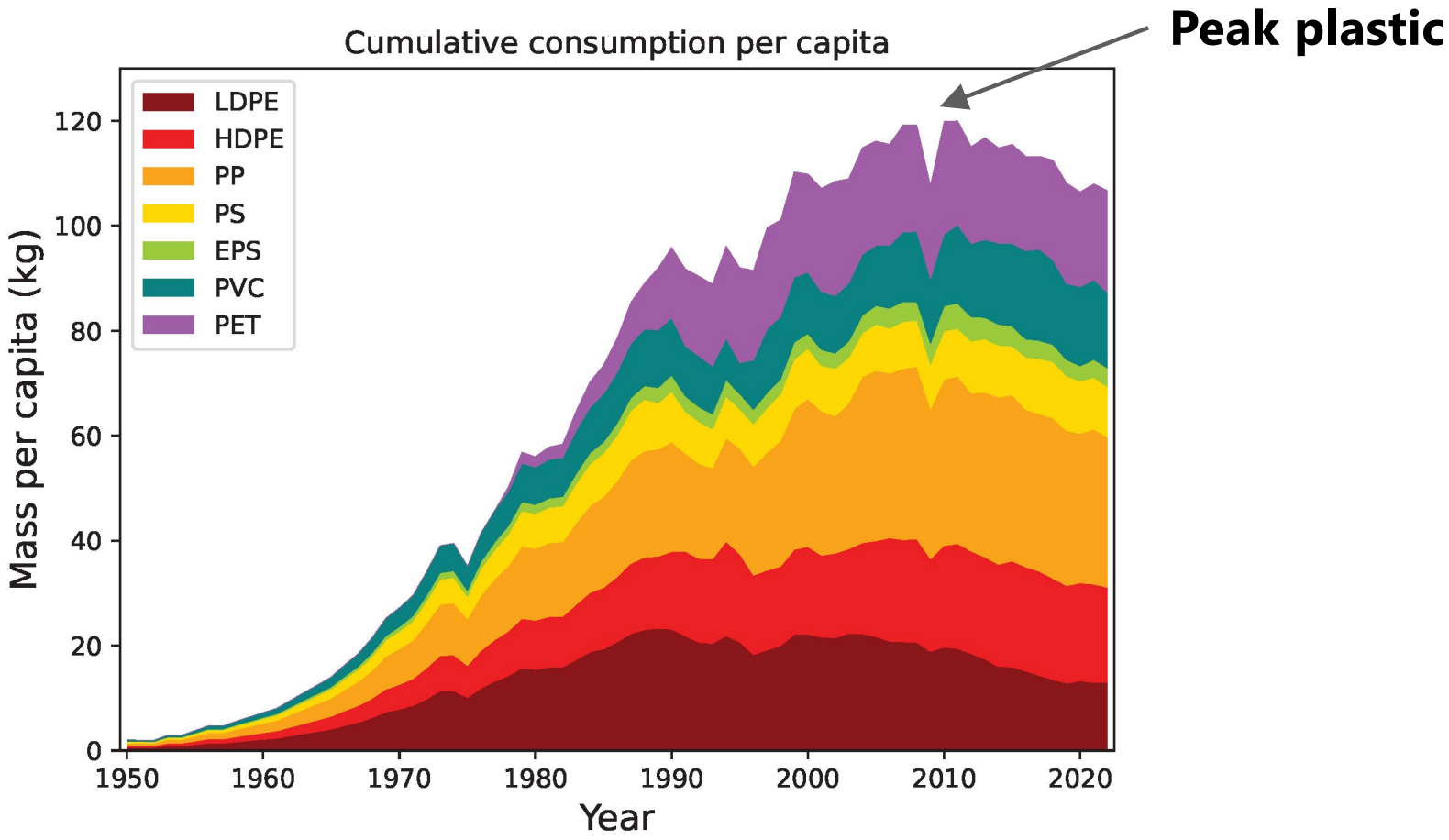

Liu and Nowack (2025) *Resources, Conservation and Recycling* 214: 108011.

The modeling approach

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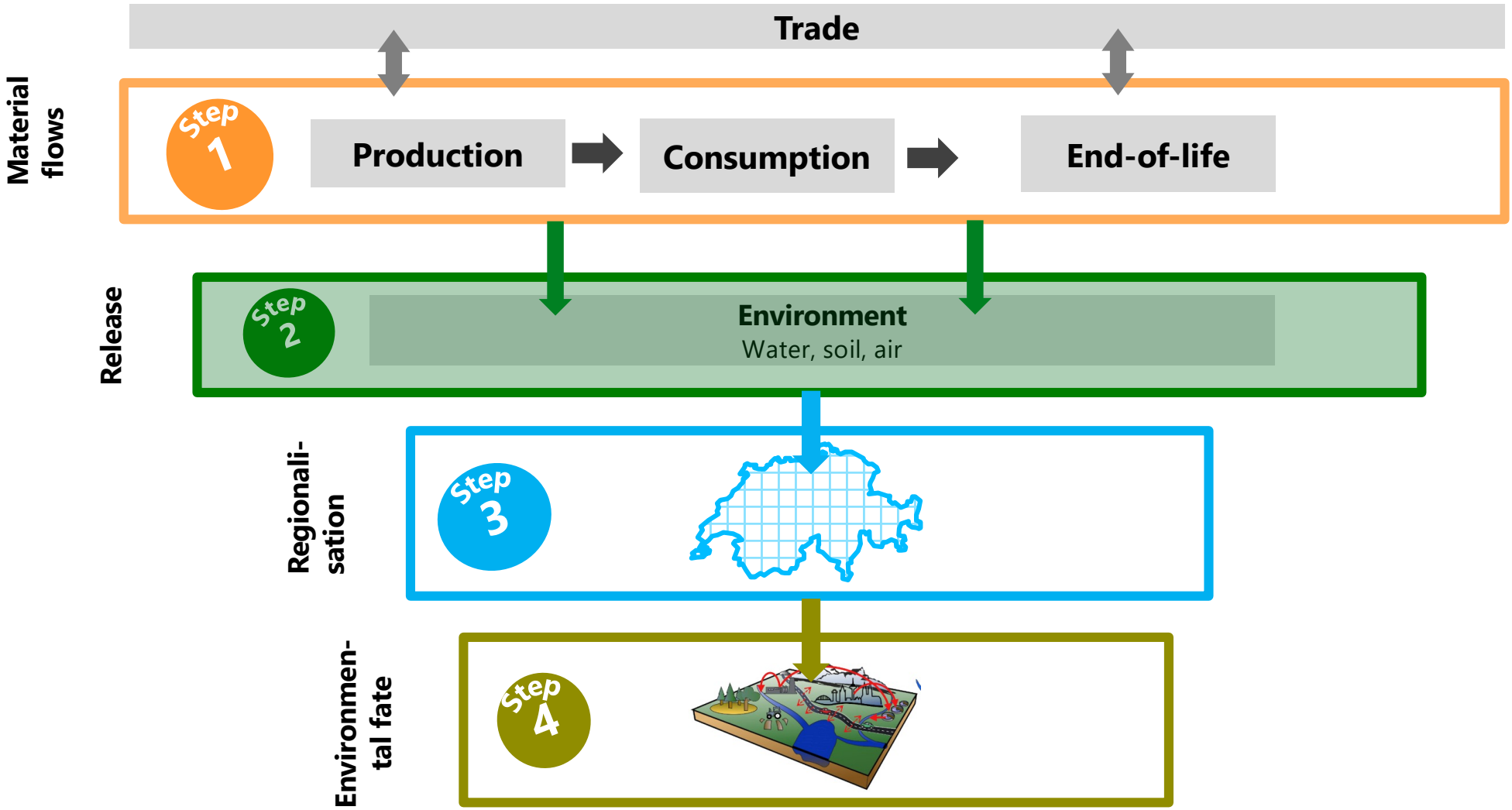

Quantification of release

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- Release assessment based on material flow models
- Identification of release processes throughout the whole life-cycle
- Parameterizing the amount released (release factors, emission factors)
- Identifying the receiving technical or environmental compartment
- Performed separately for macro- and microplastics

Plastic emissions to the environment

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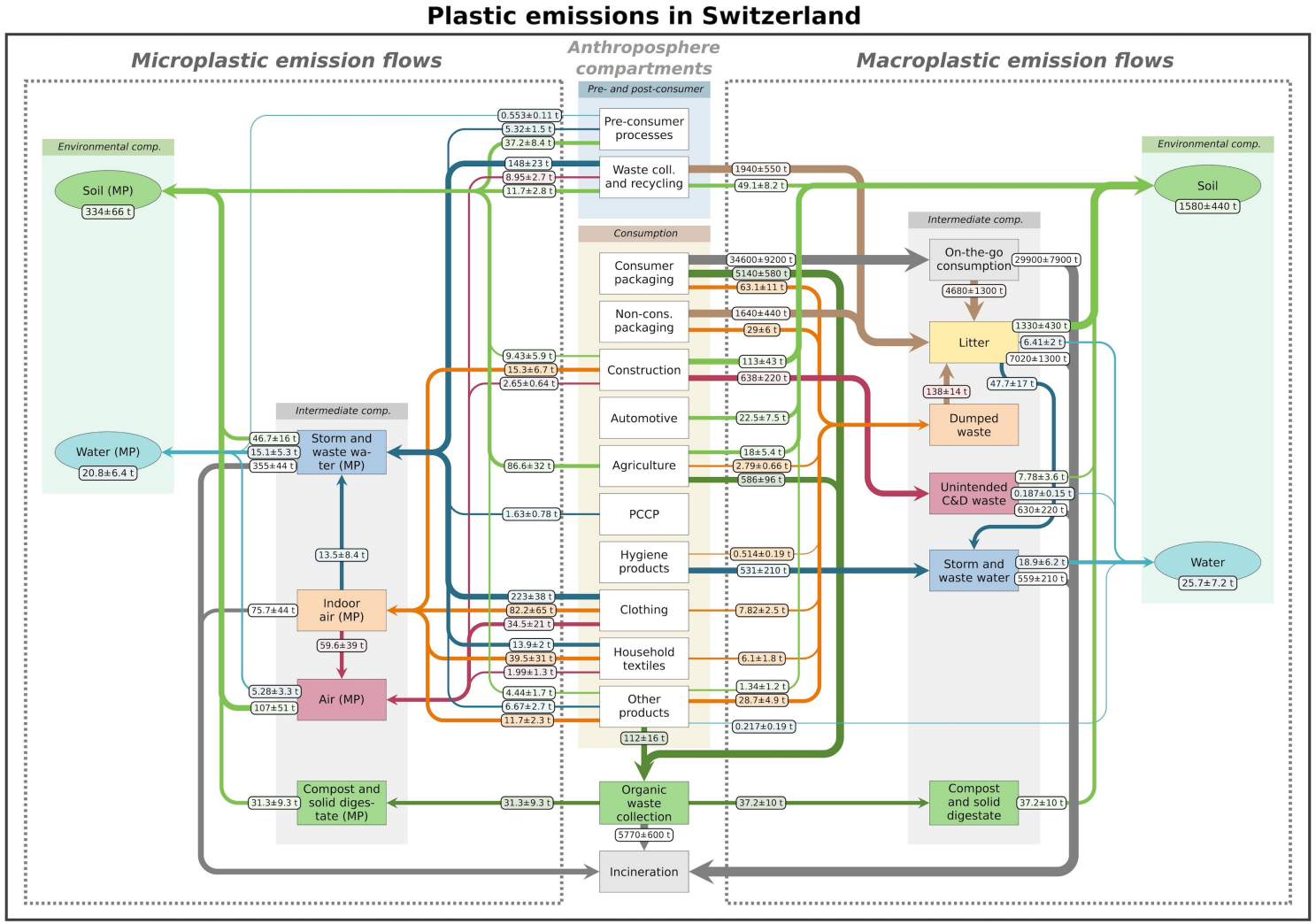

Jiang and Nowack (2025)
Environ. Pollut. 383: 126800.

Release to water in Switzerland

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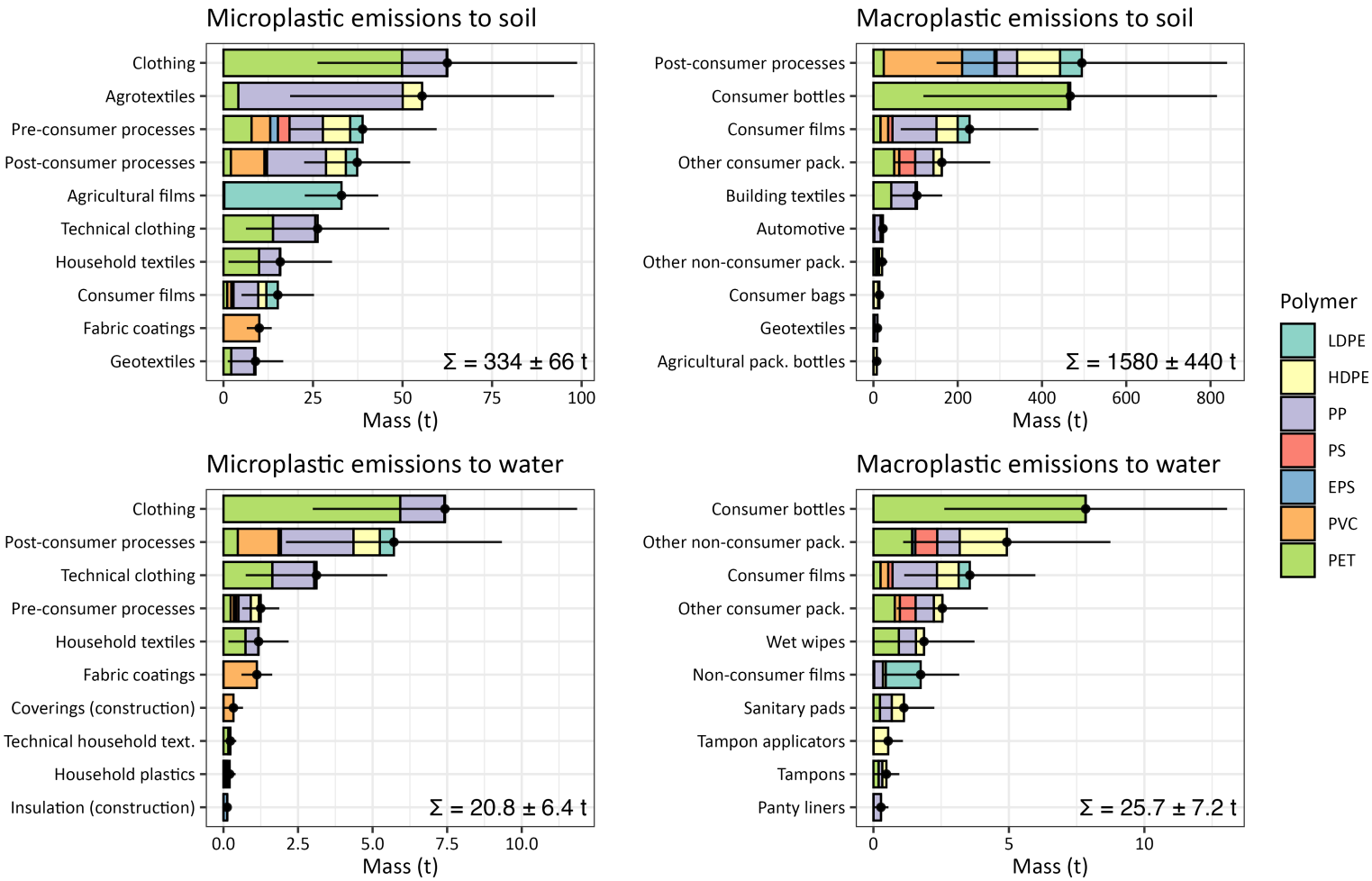

Jiang and Nowack (2025)
Environ. Pollut. 383: 126800.

Emission factors

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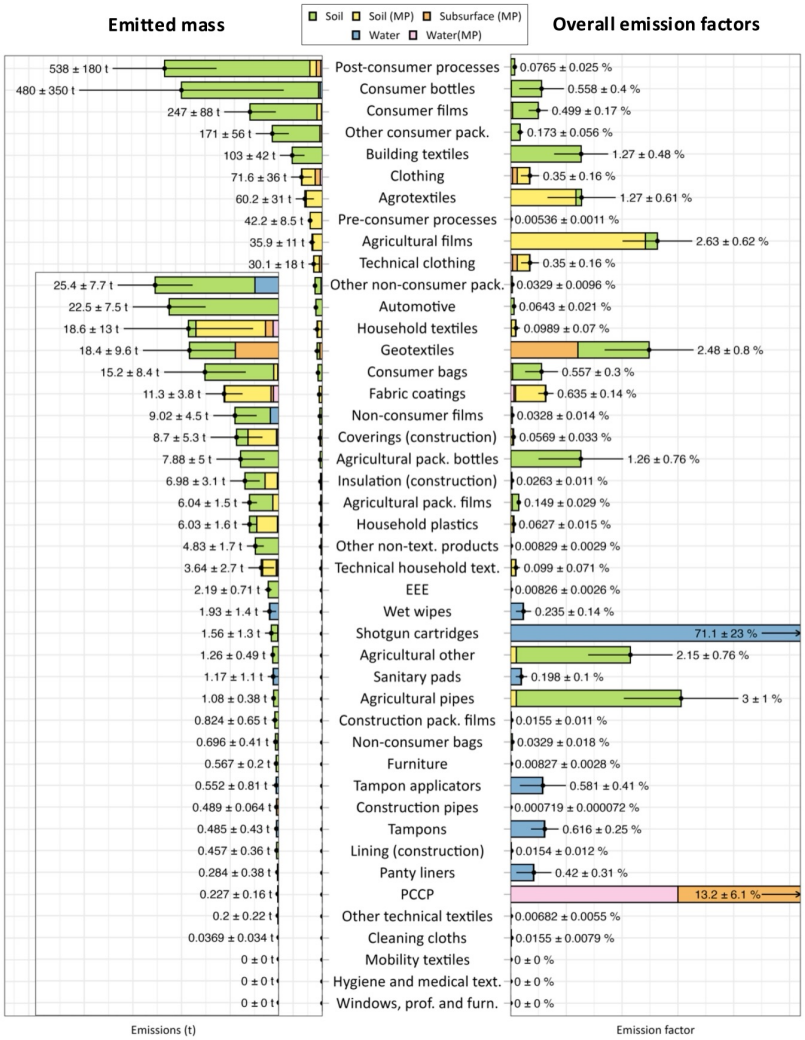

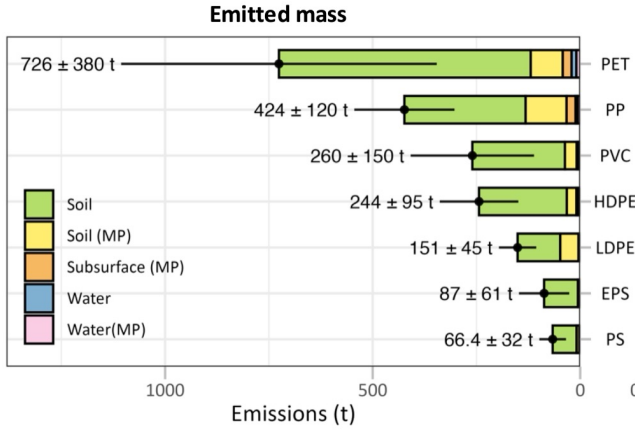

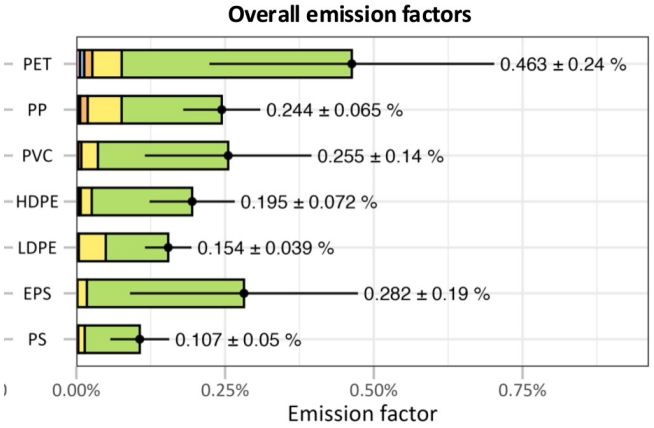

Jiang and Nowack (2025)
Environ. Pollut. 383: 126800.

Comparison of release assessments

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Study	Region	Year	Considered Polymers	Rubber emissions (g/capita)	Microplastic emissions excluding rubber (g/capita)	Macroplastic emissions (g/capita)
Jiang & Nowack, 2025	Switzerland	2022	LDPE, HDPE, PP, PS, EPS, PVC, PET	-	**40.3 ± 7.5**	**182 ± 49**
Kawecki & Nowack, 2019	Switzerland	2014	LDPE, HDPE, PP, PS, EPS, PVC, PET	-	75 ± 14	550 ± 140
Sieber et al., 2020	Switzerland	2018	Rubber	960	-	-
Schwarz et al., 2023	Switzerland	2017	LDPE, HDPE, PP, PS, EPS, PVC, PET, rubber	402	**471**	3362
Amadei et al., 2023	EU27	2019	LDPE, HDPE, PP, PS, EPS, PVC, PET, rubber, PA, PUR	72	61	3308
Ryberg et al., 2019	Global	2015	LDPE, HDPE, PP, PS, EPS, PVC, PET, rubber	192	106	644
Hoseini & Bond, 2022	Global	2015	LDPE, HDPE, PP, PS, PVC, PET, fibers, rubber	245 ± 177	232	1167
Luan et al., 2022	China	2020	PE, PP, PS, PVC, ABS, PET	-	250	**9001**

Jiang and Nowack (2025) Environ. Pollut. 383: 126800.

Plastic release fraction

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Environmental release in % of consumption

	microplastic	macroplastic	total	% as micro
PET	0.05	1.17	1.22	4
LDPE	0.12	0.53	0.64	18
HDPE	0.08	0.55	0.62	12
PP	0.10	0.51	0.61	16
PVC	0.10	0.38	0.48	21
EPS	0.02	0.38	0.40	5
PS	0.03	0.31	0.34	10
PMMA	0.06	0.26	0.32	18
PA	0.10	0.14	0.23	41
PC	0.10	0.06	0.16	61
ABS	0.10	0.03	0.14	75
PUR	0.02	0.05	0.07	30
Average	**0.08**	**0.51**	**0.58**	**19**

Liu and Nowack (2022) Resources, Conservation & Recycling 179: 106071

The European model

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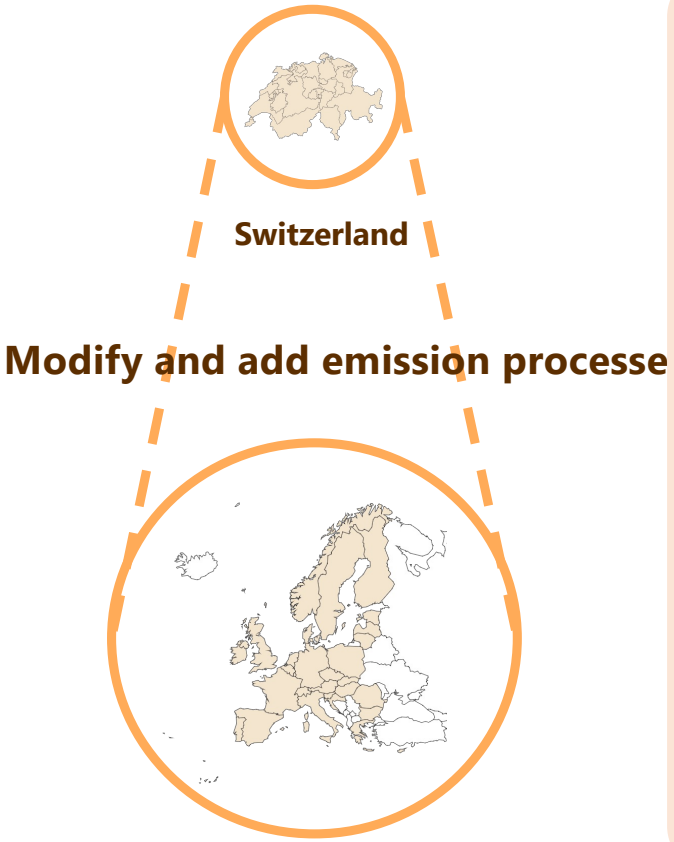


Product sectors

Packaging
Construction
Agriculture
Automotive
EEE
Other
Clothing
Household textiles
Technical textiles
+
Fishery
Aquaculture

Waste collection systems

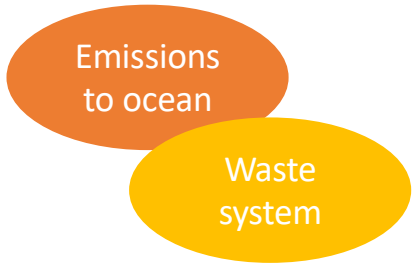
…
+
Fishing gear

Waste treatment

Incineration
Dumping
Reuse and recycling
+
Landfill

Environmental sinks

Surface water
Residential soil
Agricultural soil
Natural soil
Roadside soil
Subsurface soil
+
Ocean
Coastal water
Beach soil



➡ **Country-specific plastic release model for 30 European countries**

The modeling approach

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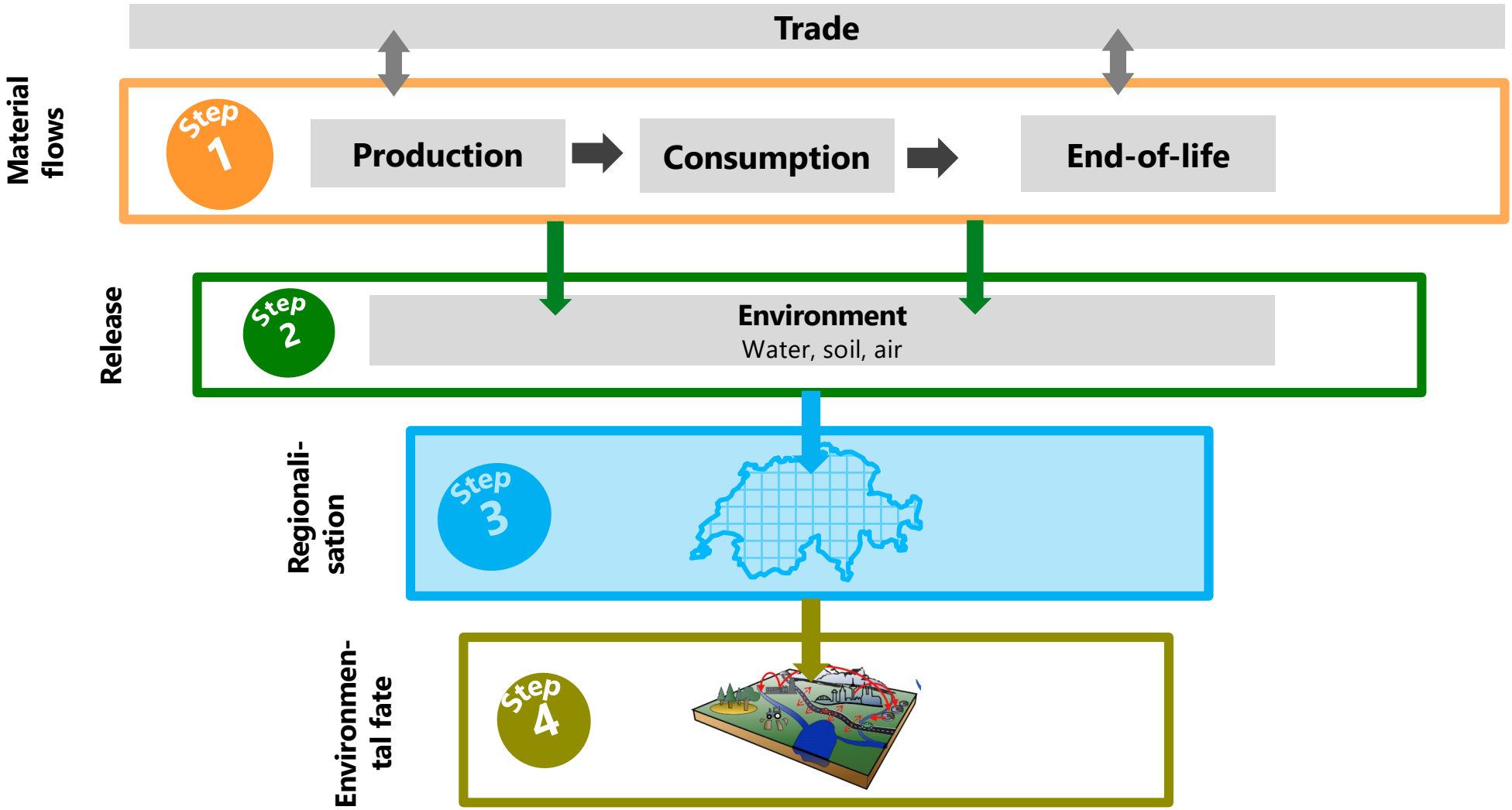

Regionalization emission flows

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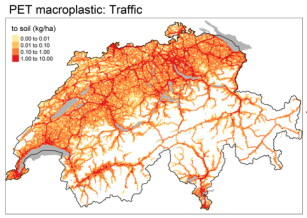
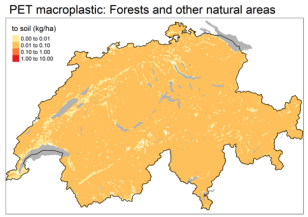
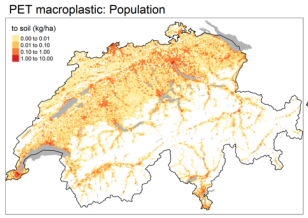
Largest emissions of PET macroplastic to soil

1. Litter to road sides: 1’246 tonnes
2. Litter to natural surfaces 145 tonnes
3. Litter to residential soil 87 tonnes
4. More emission flows $\Sigma = 70$ tonnes

Using the proxies for the summed emissions

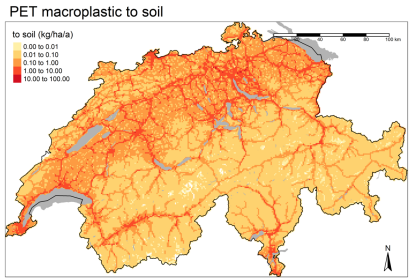






More proxies

Final result



Emission maps for Switzerland

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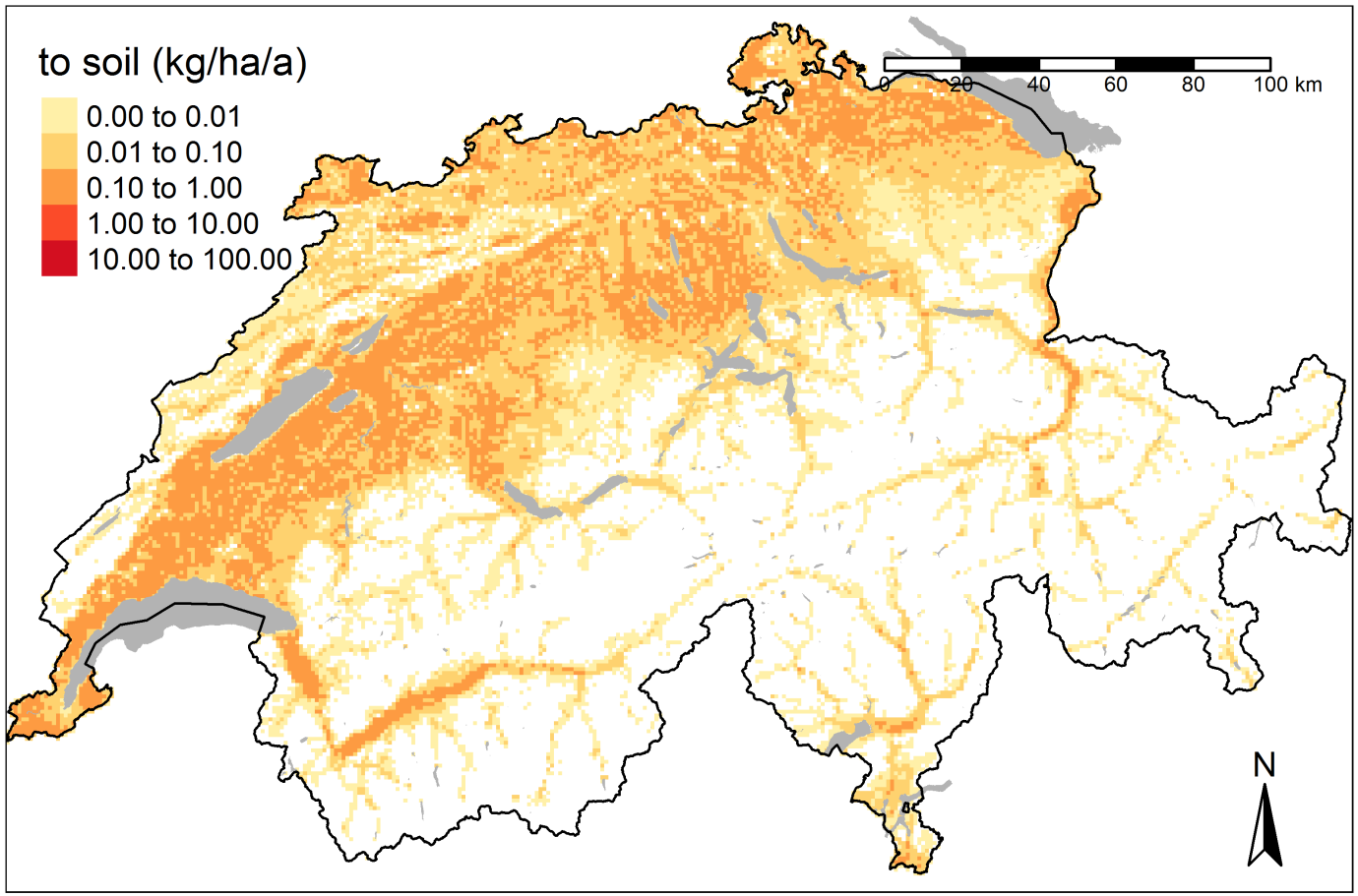
LDPE microplastic to soil



Kawecki and Nowack (2020)
STOTEN 748: 141137

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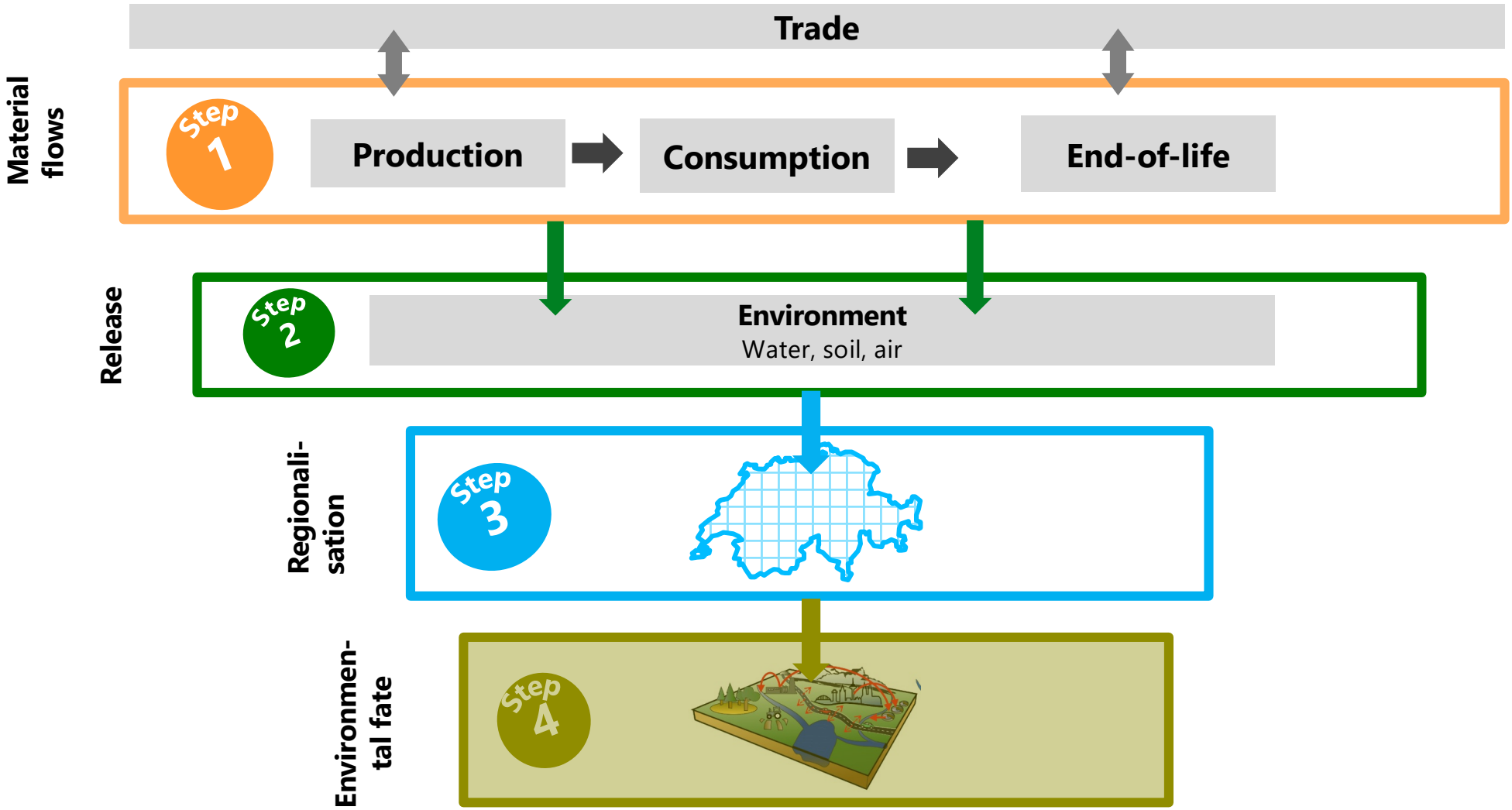

Macro- and microplastic fate models

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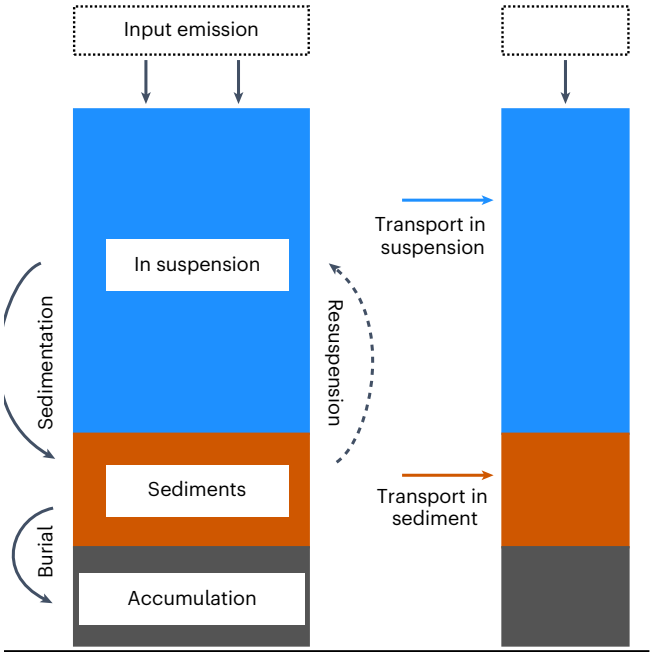
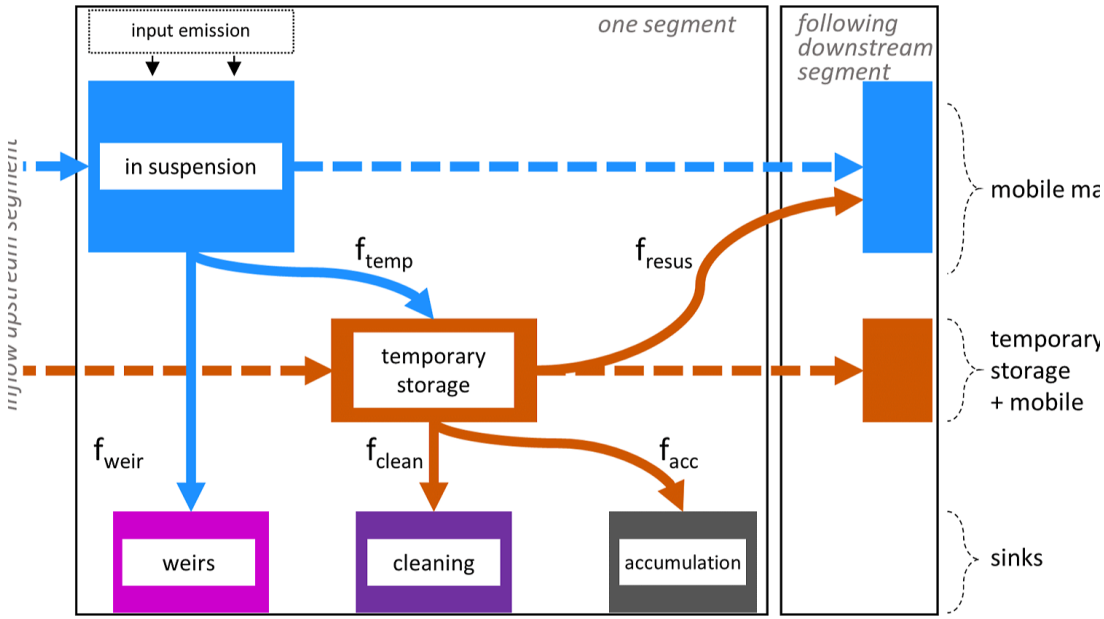
Microplastic



Mennekes and Nowack (2023) *Nature Water* **1:** 523–533.

Macroplastic



Mennekes et al (2024) *ACS ES&T Water* **4:** 2470−2481.

Macroplastic in Swiss freshwaters

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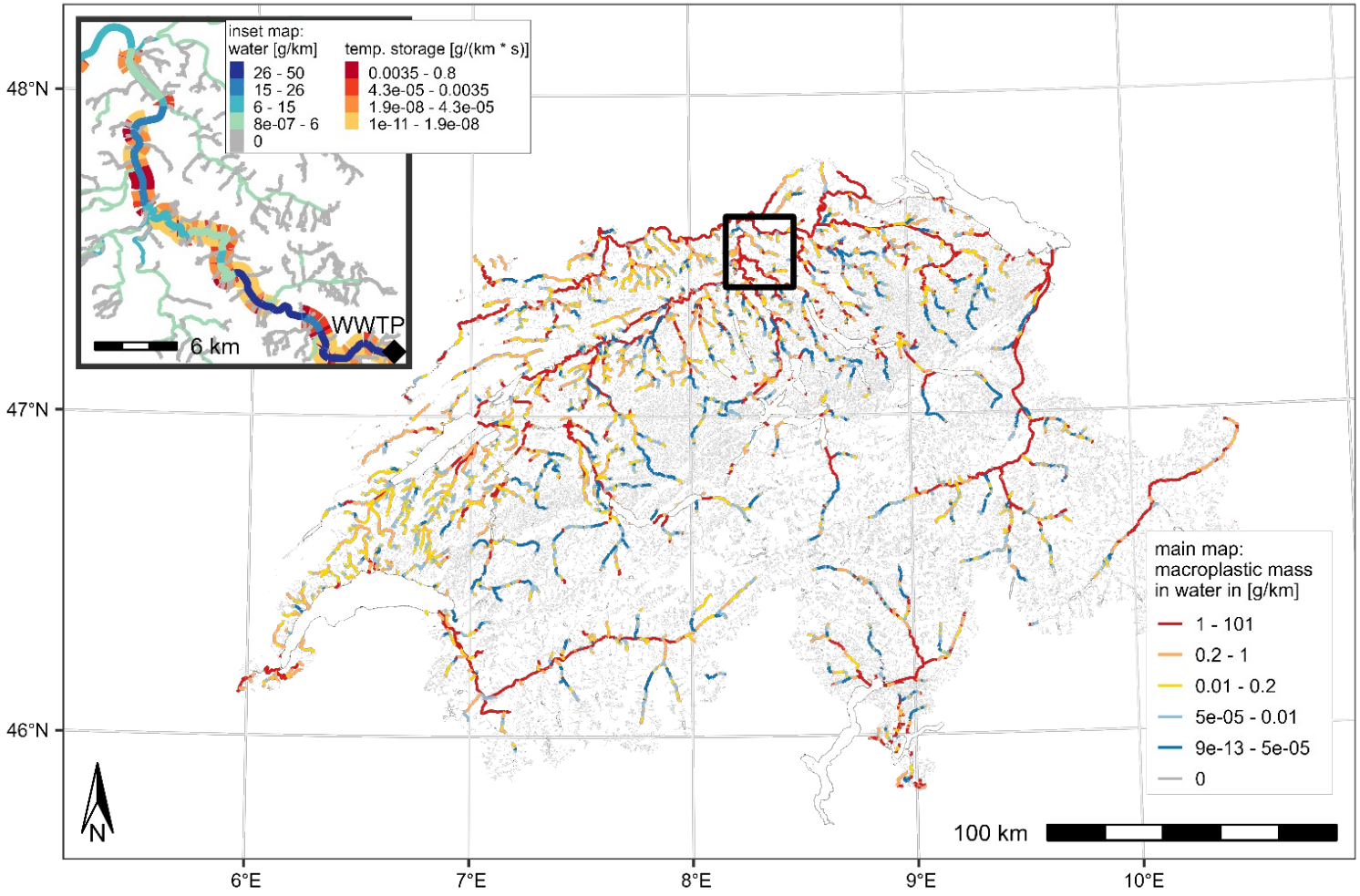

Mennekes et al (2024) *ACS ES&T Water* **4:** 2470−2481.

Comparison between macro- and microplastics

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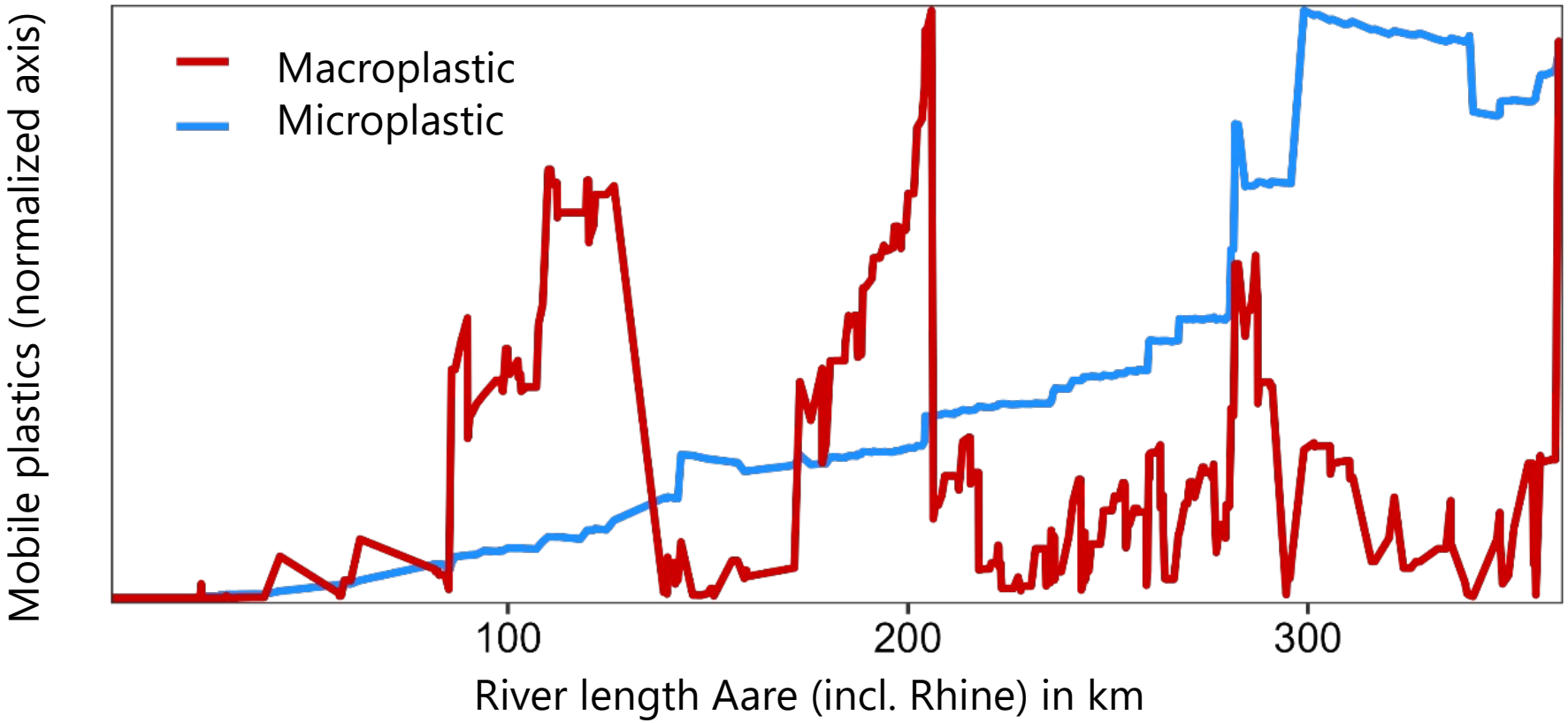

Mennekes und Nowack (2024)
Aqua und Gas 6/2024: 44-49.

Conclusions

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- Life-cycle based view allows prediction of plastic releases
- Knowledge about release processes is key for quantification
- Plastic releases in Switzerland are much smaller than all other published release estimates
- First country-specific release estimates obtained
- Coupling of a chain of models allows prediction of environmental concentrations

Outlook

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- Fragmentation in the environment not part of the model
- Soil and water releases are not yet linked
- Microplastic particle size is not yet included

Acknowledgements

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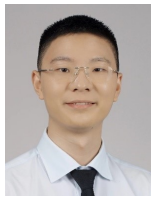
Delphine Kawecki

David Mennekes

Danyang Jiang

Zipeng Liu



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LRI Long-Range Research Initiative

cefic

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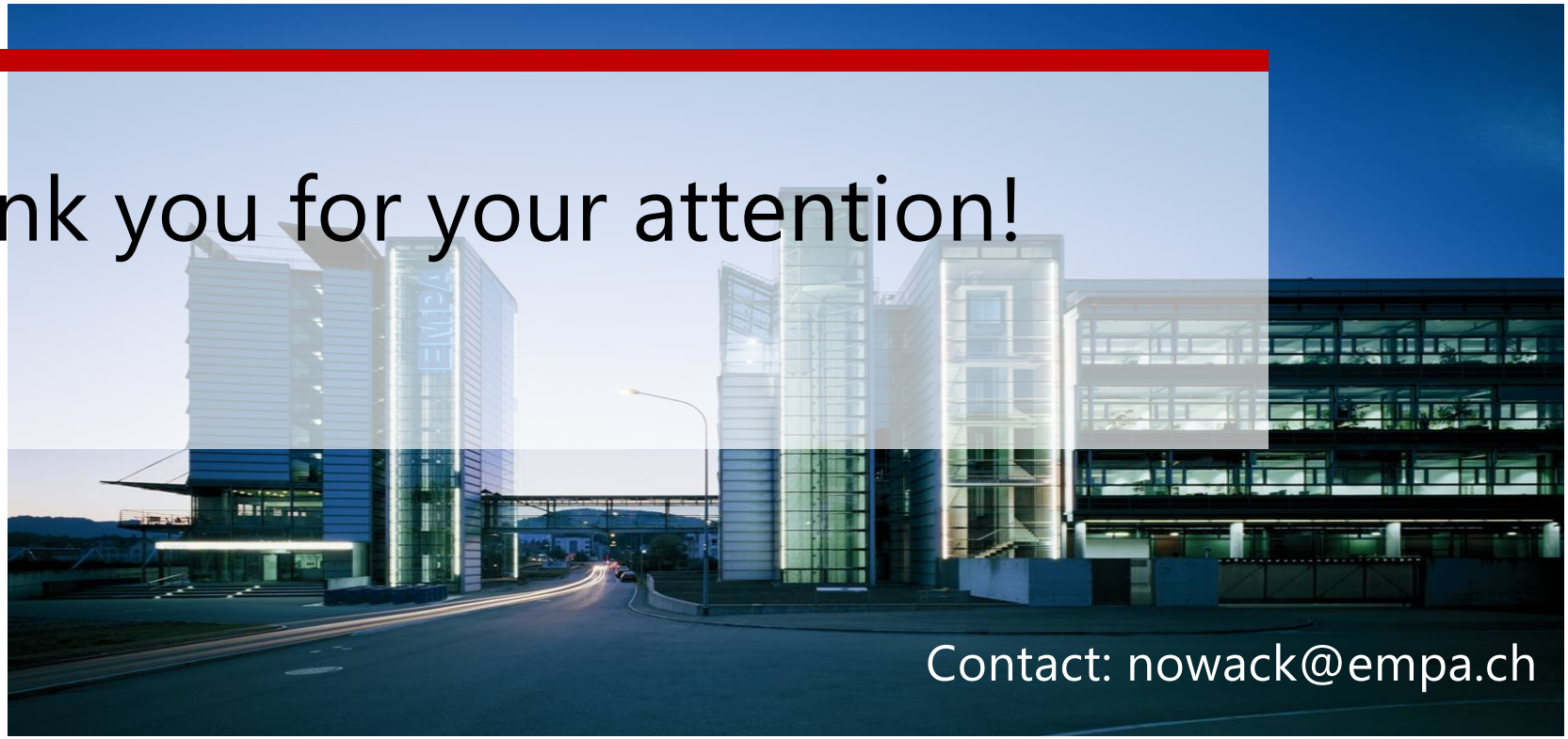
Thank you for your attention!



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