MarILCA
MARINE IMPACTS IN LCA

LCA Discussion Forum – November 4, 2022

# New characterization factors for microplastic emissions of 9 polymers in the aquatic environment

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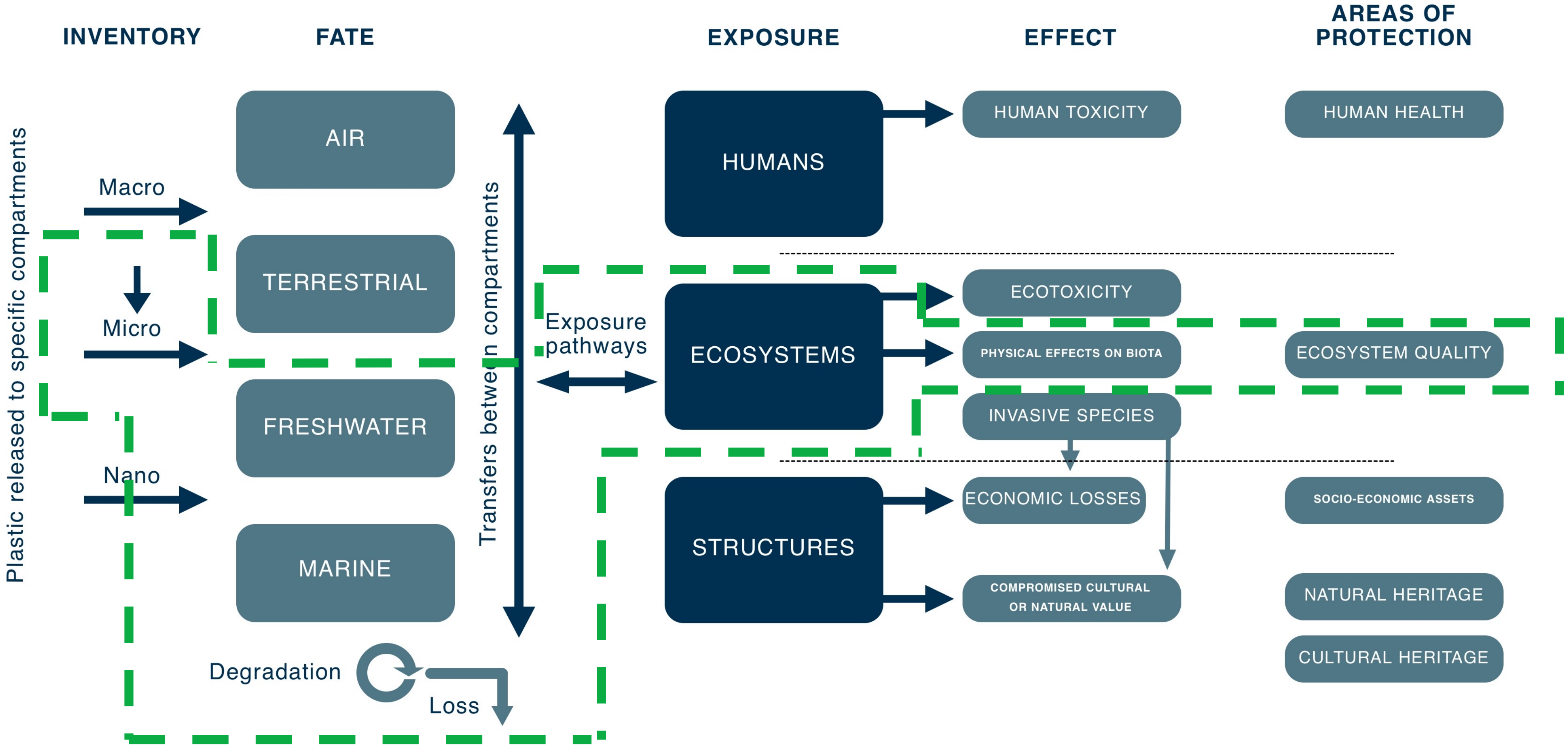
POLYTECHNIQUE MONTRÉAL

# MarILCA (MARine Impacts in LCA)




Adapted from Woods, J. S., Verones, F., Jolliet, O., Vázquez-Rowe, I., & Boulay, A. (2021). A framework for the assessment of marine litter impacts in life cycle impact assessment. *Ecological Indicators*, *129*, 107918.

# Characterization factor (CF) methodology

*Microplastic emission * CF = Damage on ecosystem quality*

[kg plastic] [species*year] / [PDF*m$^2$*year]

*CF = Fate factor * Exposure factor * Effect factor*

Distribution and longevity of microplastics

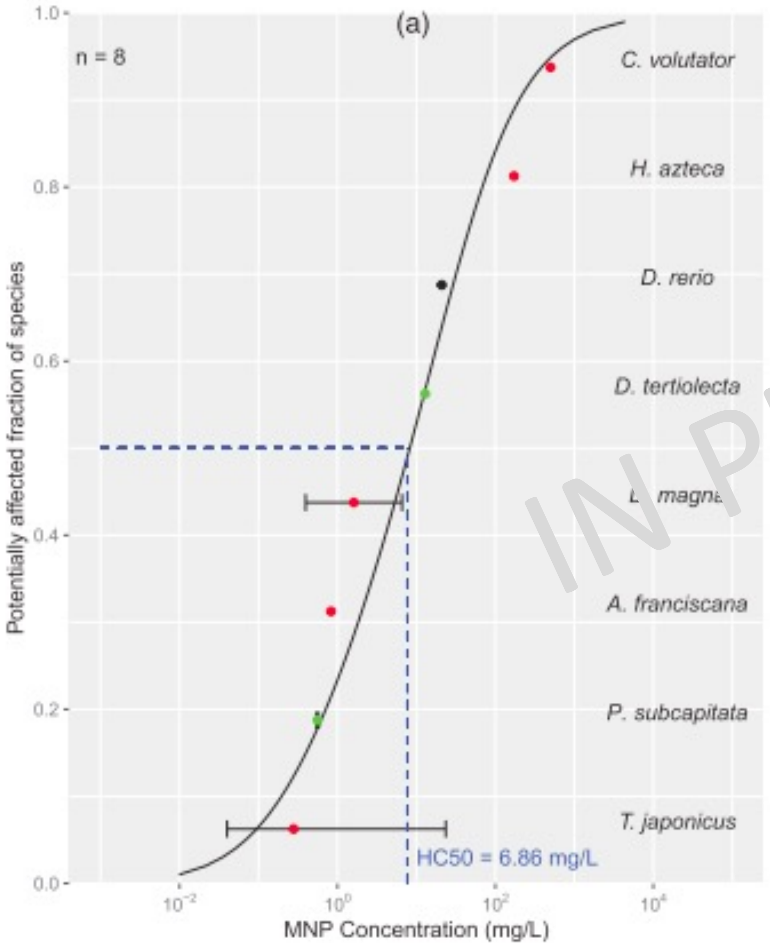
Ingestion of microplastics

$XF = 1 \frac{kg_{bioavailable}}{kg_{in\ compartment}}$

Animal health issues, reproductive impairment

Combined EEF

# Exposure and effect factor (update from Lavoie et al. 2021)




Methodology:

$$EEF = \frac{0.5}{HC50}$$

HC50 = geometric mean of EC50s or LC50s



Results:

Lavoie et al. 2021:

- 13 chronic EC50s or LC50s
- EEF: 72.9 (7.22–736.41) PAF $m^3/kg_{in\ compartment}$

This work:

- 22 chronic EC50s or LC50s
- EEF: 38.4 (8.4–175.4) PAF $m^3/kg_{in\ compartment}$

Lavoie, J., Boulay, A., & Bulle, C. (2021). Aquatic micro- and nano-plastics in life cycle assessment: Development of an effect factor for the quantification of their physical impact on biota. *Journal of Industrial Ecology*, (2015), 1–13.

# Fate factor methodology

| Rate (day$^{-1}$) | Onshore beach. C | Water surface. C | Water Column. C | Sediments. C | Water surface. G | Water column. G | Sediments. G |
|---|---|---|---|---|---|---|---|
| Onshore beach. C | $-k_{b.C, tot}$ | $k_{b.C \leftarrow ws.C}$ | $k_{b.C \leftarrow wc.C}$ | $k_{b.C \leftarrow sed.C}$ | $k_{b.C \leftarrow ws.G}$ | $k_{b.C \leftarrow wc.G}$ | $k_{b.C \leftarrow sed.G}$ |
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Fate matrix:

$$\overline{FF} = -\bar{k}^{-1}$$

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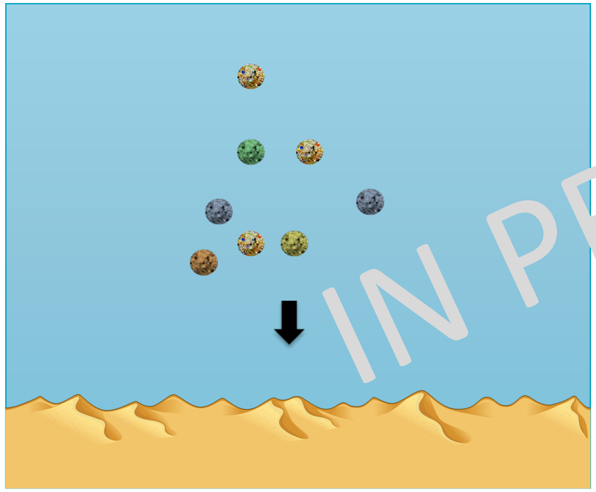
| Rate (day$^{-1}$) | Water |
|---|---|
| Water | $-k_{water,tot}$ |

$$k_{degradation} + k_{sedimentation}$$

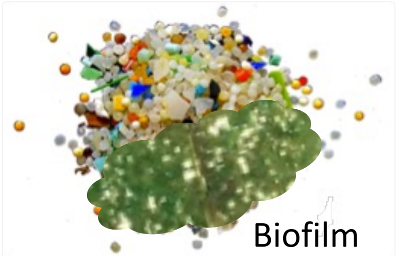
# Fate factor methodology

## Sedimentation



- Based on polymer density
- $1^{st}$ order kinetics

## Degradation




- Based on surface degradation
- $1^{st}$ order kinetics



**Scenarios: worst, medium, best**

# Fate factor methodology

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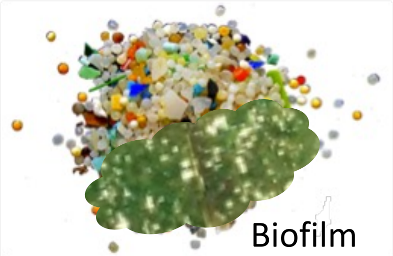
## Degradation

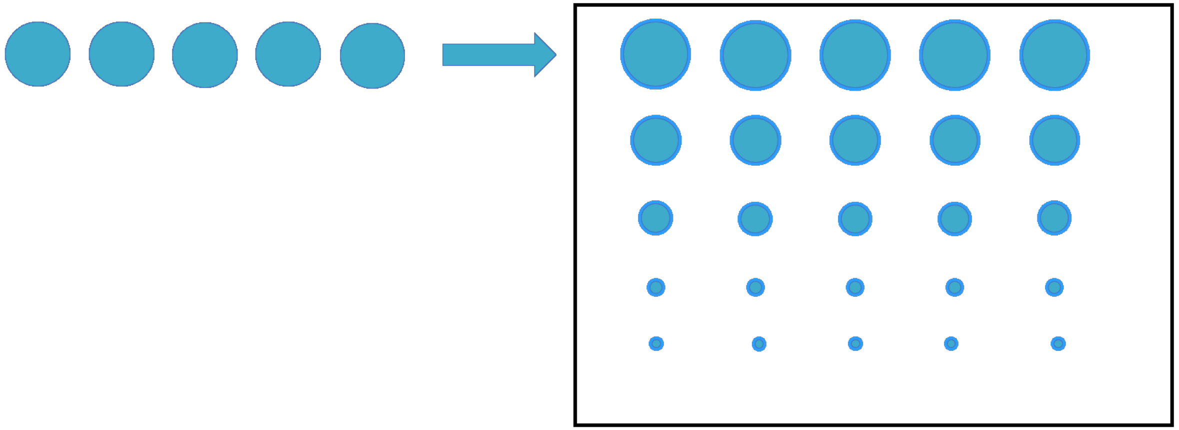
Approach (Chamas et al. 2020): (I) $$\frac{dM(t)}{dt} = -k_D \rho S A(t)$$

For a sphere of radius r: (II) $$\frac{dM(t)}{dt} = -k_D \rho 4\pi r(t)^2 \, f_c$$






In a steady state:



- Based on surface degradation
- 1st order kinetics



Chamas, A., Moon, H., Zheng, J., Qiu, Y., Tabassum, T., Jang, J. H., … Suh, S. (2020). Degradation Rates of Plastics in the Environment. *ACS Sustainable Chemistry and Engineering*, *8*(9), 3494–3511. https://doi.org/10.1021/acssuschemeng.9b06635

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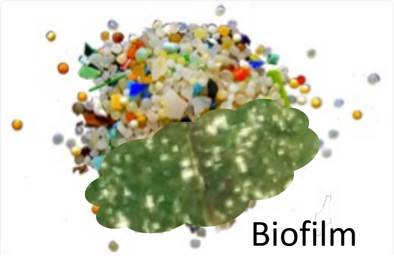
# Fate factor methodology



## Degradation






$k_{degradation}$

Sphere: $\frac{dM(t)}{dt} = -M\frac{4k_D f_c}{r_{max}}$

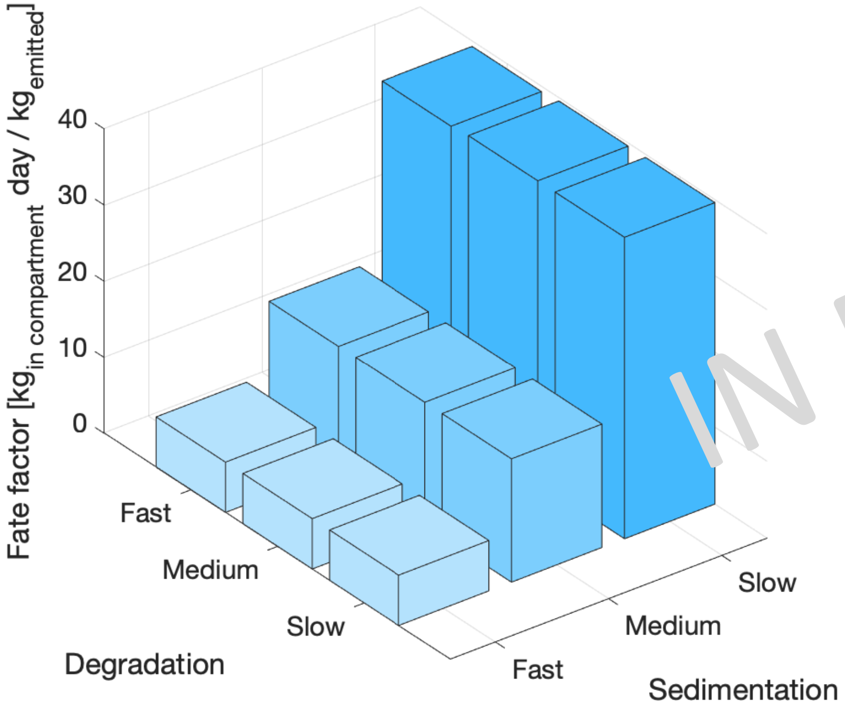
Fiber: $\frac{dM(t)}{dt} = -M\frac{3k_D f_c}{r_{max}}$

Film: $\frac{dM(t)}{dt} = -M\frac{2k_D f_c}{r_{max}}$

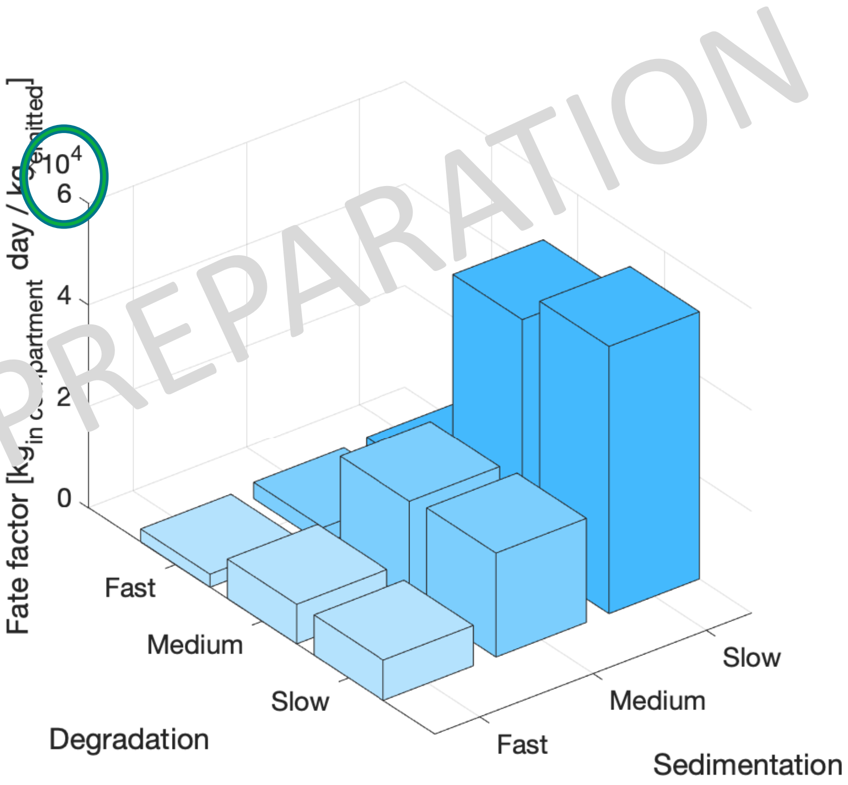
- Based on surface degradation
- 1st order kinetics

# Fate factor results

PLA

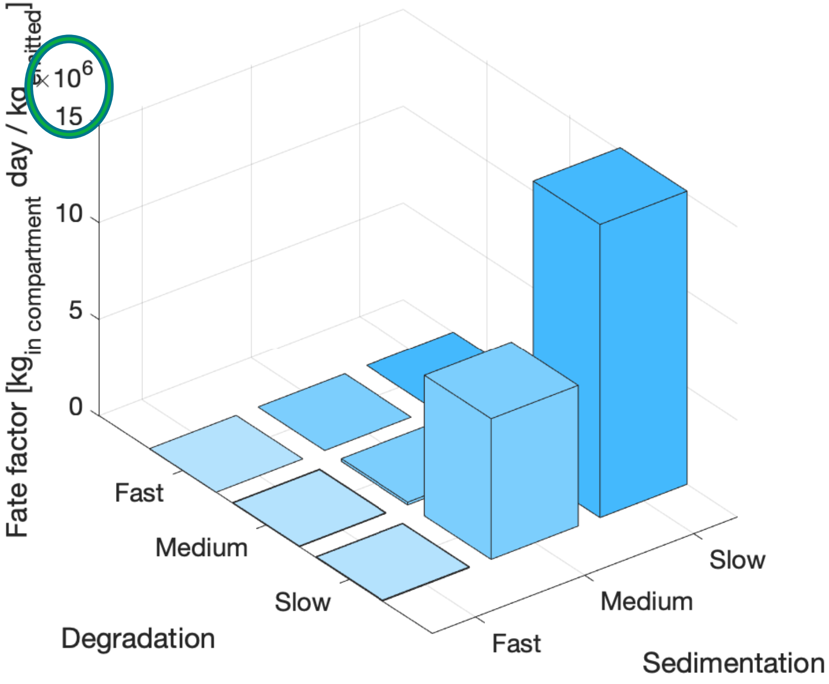



HDPE





EPS



# Marine characterization factors

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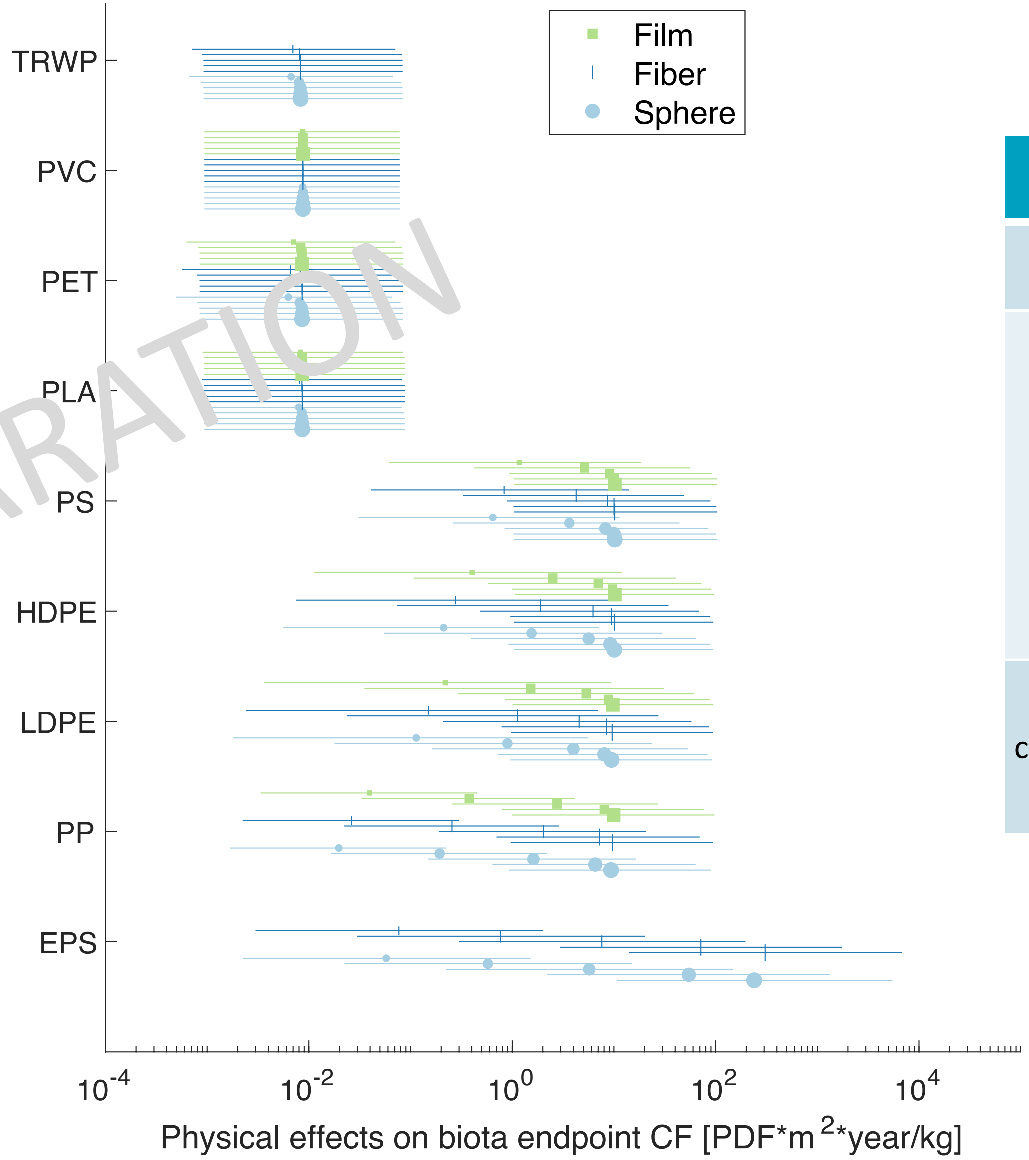
High-density polymers

Medium-density polymers

Low-density polymers




| Factor | Parameter |
|---|---|
| Effect factor | Hazardous concentration 50% based on EC50s |
| Fate factor | Initial particle size |
| | Specific surface degradation rate |
| | Surface area correction factor |
| | Sedimentation rate |
| Endpoint characterization factor | Water depth |
| | Severity factor |

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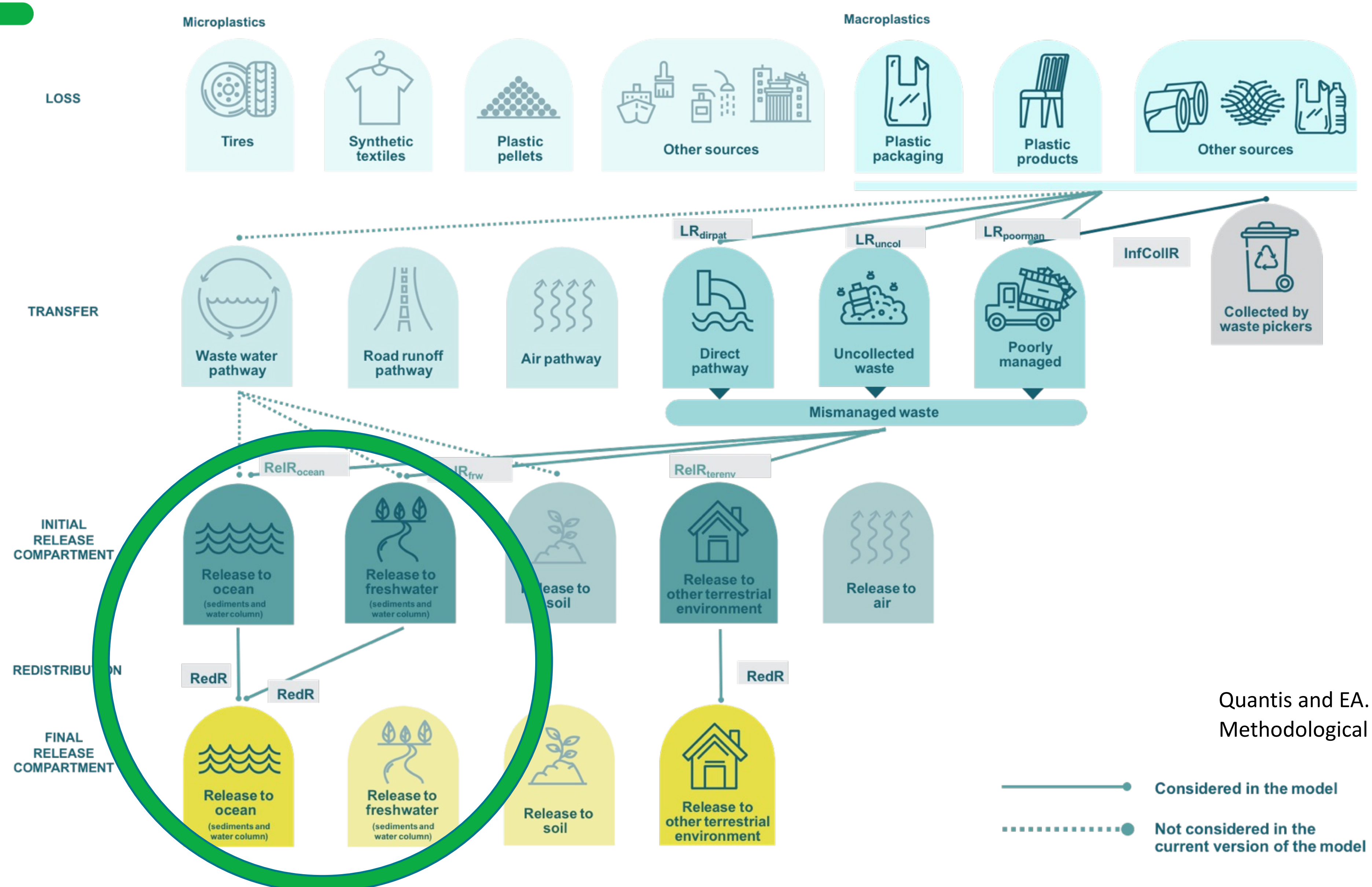
# Freshwater characterization factors


$$\tau_{freshwater} \ll \tau_{marine}$$

*Freshwater CF = 70% Marine CF*

Quantis and EA. (2020). Plastic Leak Project - Methodological Guidelines, *v1.3*(May).

# Plastic inventory (Plastic Leak Project)




Quantis and EA. (2020). Plastic Leak Project - Methodological Guidelines, *v1.3*(May).

# Conclusions & outlook

- CF for *physical effects on biota* of microplastic emissions were proposed for 9 polymers, 3 shapes and 5 sizes
- Fate of high-density microplastics: sedimentation >> degradation
- Fate of low-density microplastics: high uncertainty
- Methodology to be submitted soon!
- Will be integrated in GLAM recommendations
- Next steps: detailed sedimentation modelling

# Thank you!

# Questions?

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Postdoctoral researcher

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