

Case studies that show the predictive modelling of microplastic accumulation in the natural environment

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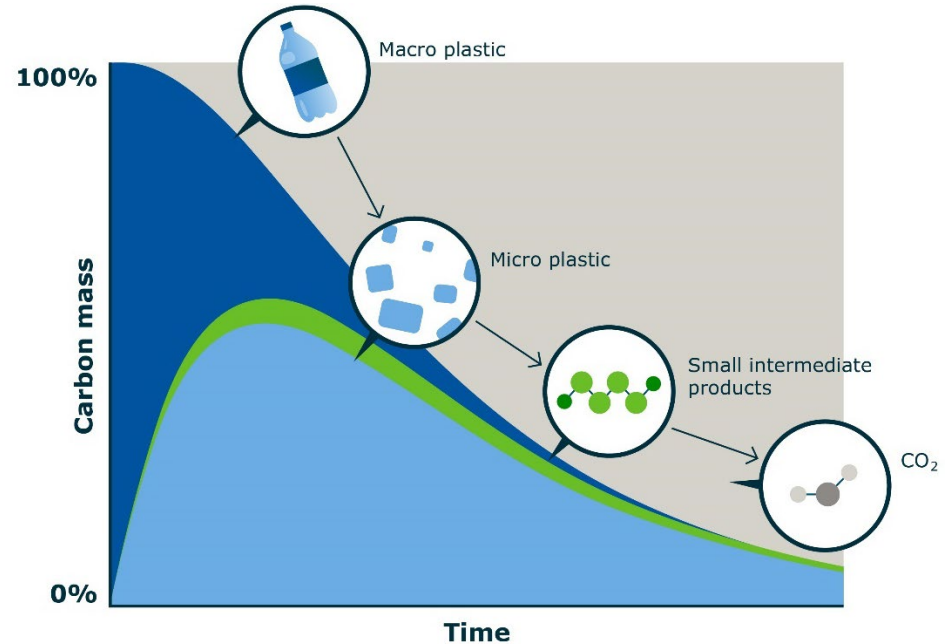
Background

- Plastic are **important** in modern daily life. However, **leakage** towards the natural environment raises concerns.
- **Biodegradability** is not included in standard LCA studies.
- Therefore, we **quantify** the microplastic exposure & accumulation from polymers and plastic products



Conceptual basis

- All polymers biodegrade
- Mass balance
- Exposure to microplastics over time
- Accumulation Potential



Modelling approach

- Set of ordinary differential equations in time.
- Fit system parameters to CO₂ evolution in time
- **See publication:**
Brouwer, et al. 2024,
A predictive model to assess the accumulation of microplastics in the natural environment.
<https://doi.org/10.1016/j.scitotenv.2024.177503>

A predictive model to assess the accumulation of microplastics in the natural environment

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HIGHLIGHTS

- Integrated biodegradation model enables the assessment of microplastic accumulation

Accumulation potential defined as time-integrated concentration of microplastics

Biodegradability leads to significantly lower accumulation potential

GRAPHICAL ABSTRACT

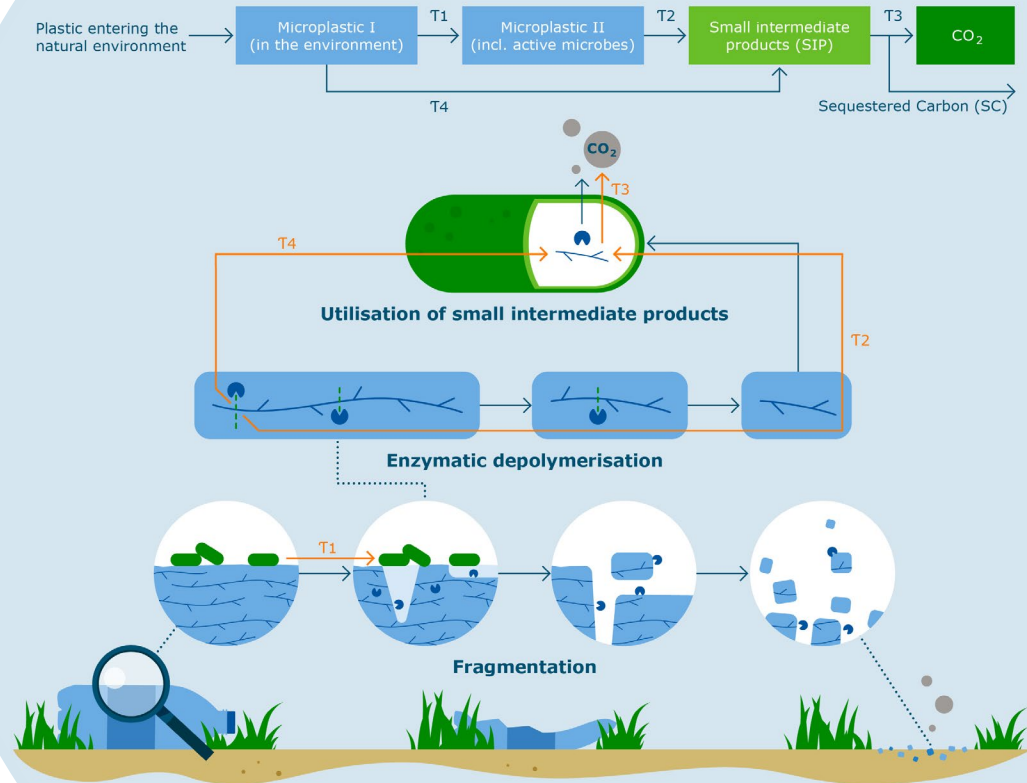
The accumulation of microplastics in the natural environment

Plastic entering the natural environment =

Amount of plastic

Model

- Describes degradation behaviour of polymers
- Fits well with what we know about biodegradation process dynamics
- Suitable for all polymer types (fast and slow/non degrading polymers)

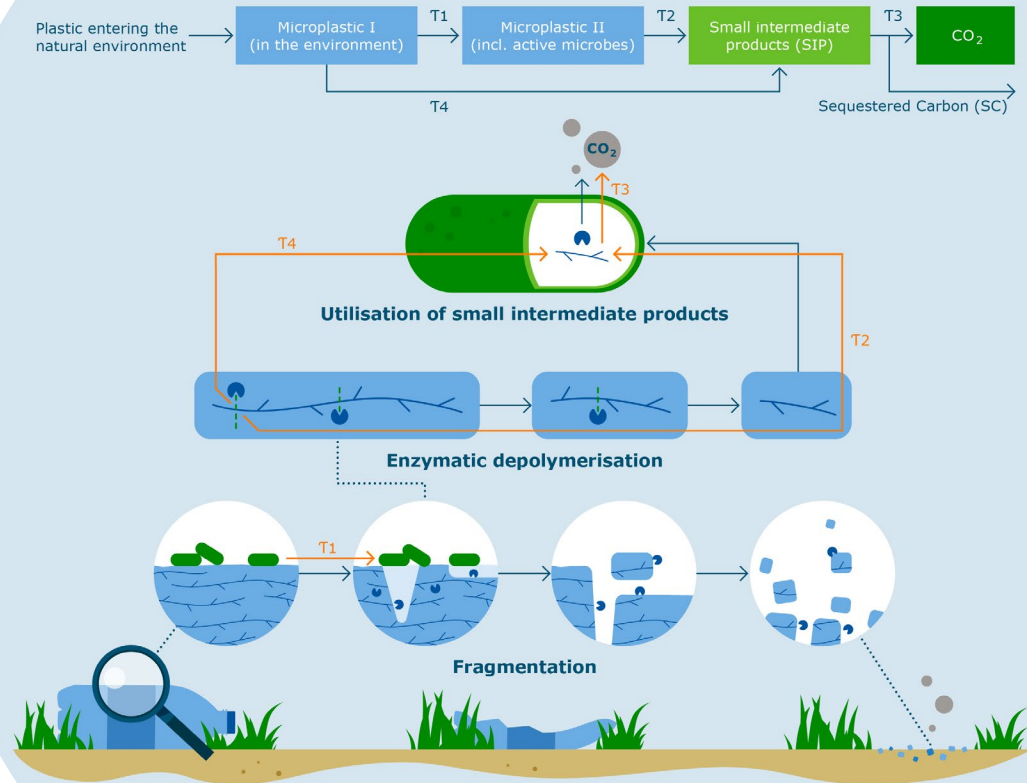


Application

Determine and compare:

- Accumulation potential
- Exposure to microplastics
- Continuously or seasonally

Implement the impact of microplastic pollution in life cycle assessment (LCA)



Database

- Data from literature

- Different:

- Polymers,
- Polymer blends,
- Environments,
- Conditions.

Disclaimer: data from polymer blends have specific compositions

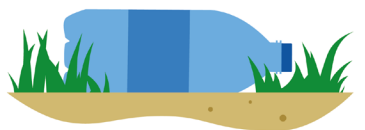


Polymer	Environment			Count
	aqueous aerobic	marine	soil	
HDPE	no fit	no data	no data	
LDPE	no data	3	1	
P3H4HB	no data	7	1	
PBAT	1	no fit	no data	
PBAT (unknown)	no data	no data	1	
PBAT-PBSeT	no data	1	no data	
PBAT-PBSeT-PLA	no data	no fit	no data	
PBAT-PLA	1	3	2	
PBS	1	1	4	
PBSA	1	1	2	
PBSe	no data	4	6	
PBSeT	no data	4	2	
PCL	2	1	no fit	
PET	1	no fit	no fit	
PET-cotton	2	1	1	
PHA (unknown)	no data	no data	2	
PHB	2	2	2	
PHBV	2	no data	2	
PLA	no data	1	3	
PLA-PCL	no data	no data	2	
PLLA	1	no data	no data	
PVA	no data	no data	1	
cotton	3	1	2	
lyocell	no data	no fit	no data	
modal	no data	no fit	no data	
rayon	1	no fit	no data	
viscose	1	no fit	no data	

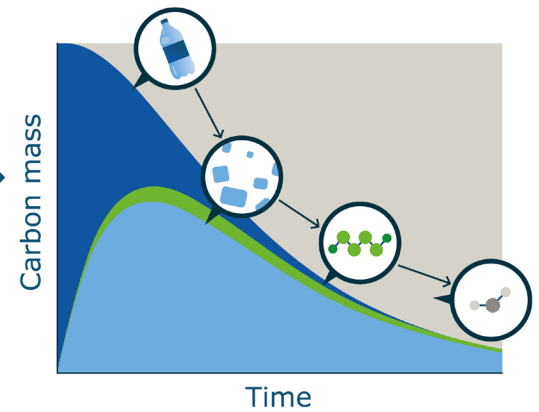
The accumulation of microplastics in the natural environment

Plastic entering the natural environment

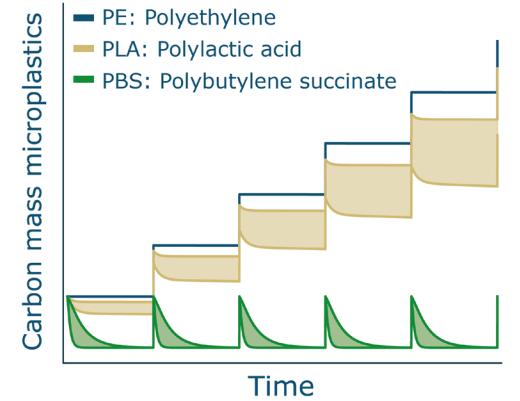
$$\begin{aligned} &= \\ &\text{Amount of plastic} \\ &\text{on the market} \\ &\times \\ &\text{Littering potential} \end{aligned}$$



Biodegradation model



Accumulation potential



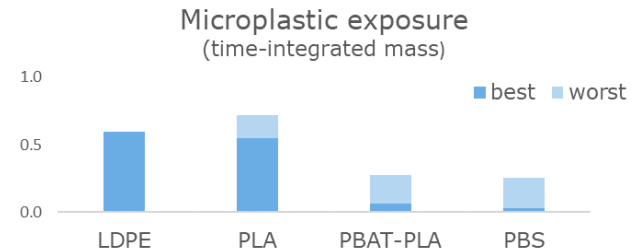
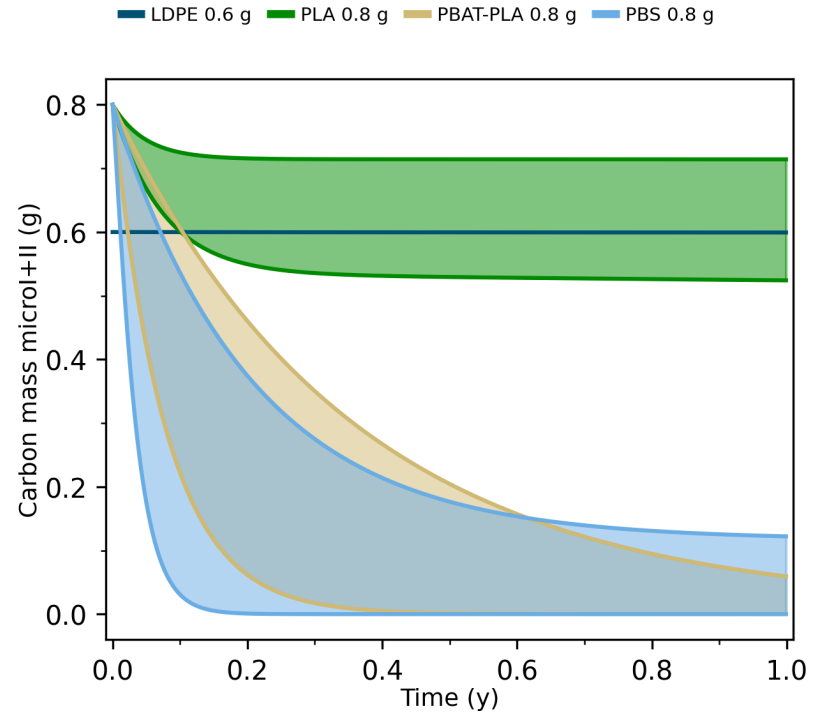
Case: Candy Wrapper

Goal:

- Compare material options for a candy wrapper

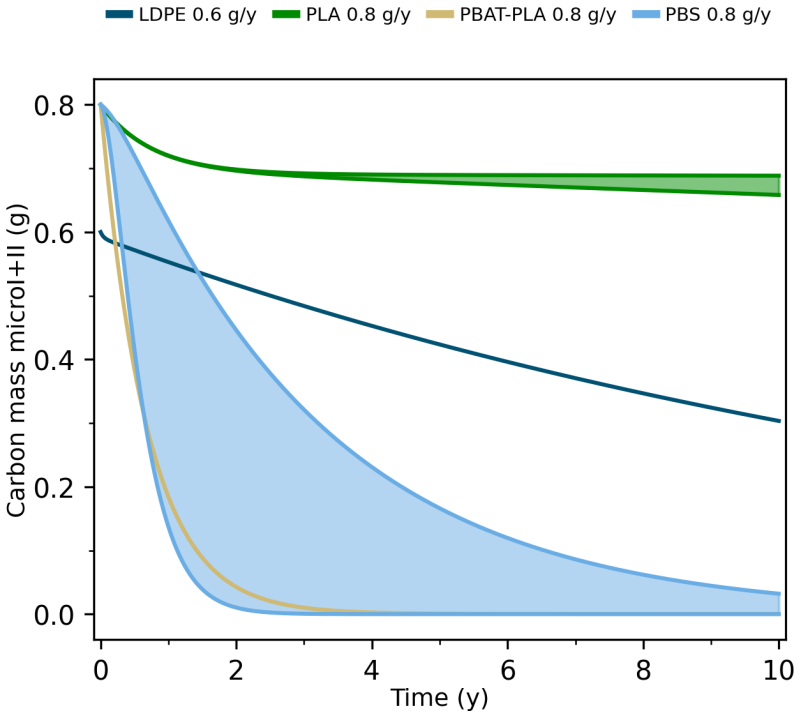
Functional Unit:

- Littering of 1 candy wrapper
- To soil environment

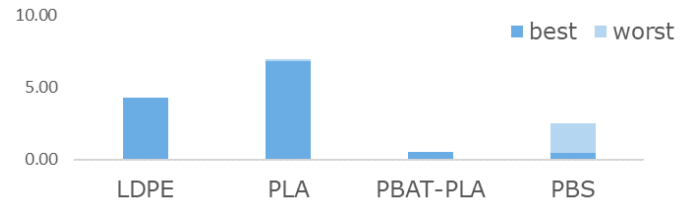


Case: Candy Wrapper

What if these wrappers end up in a **marine environment?**



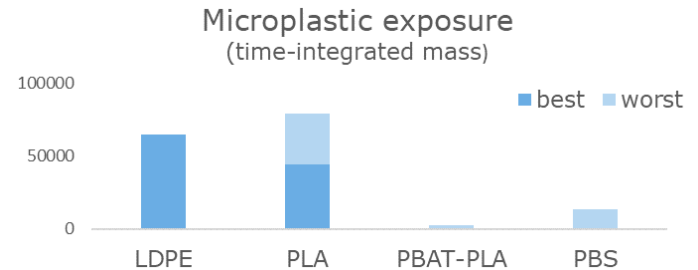
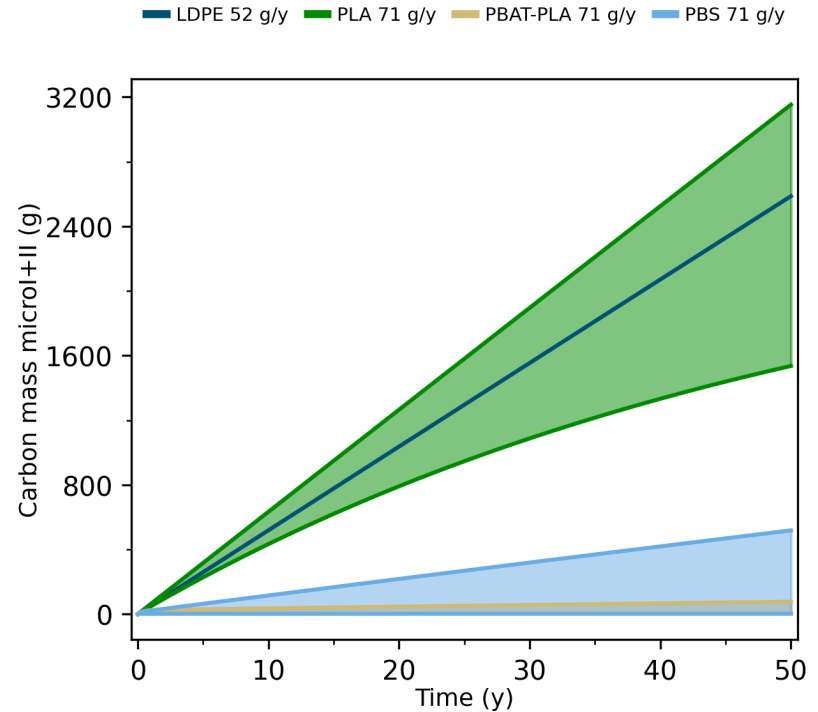
Microplastic exposure
(time-integrated mass)



Case: Candy Wrapper

What if the candy wrappers are **continuously** littered to a soil environment?

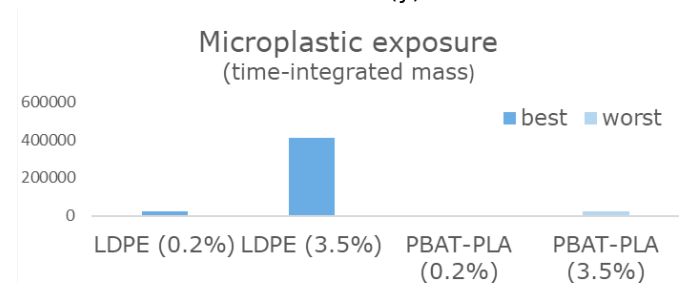
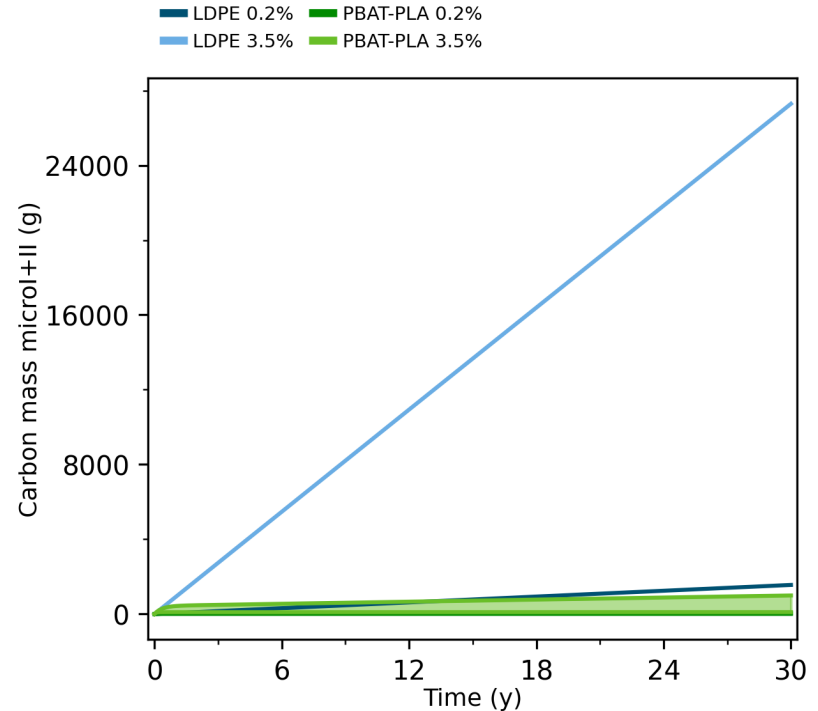
- 45 million wrappers used per year in NL
- Littering rate of 0.2%



Case: Candy Wrapper

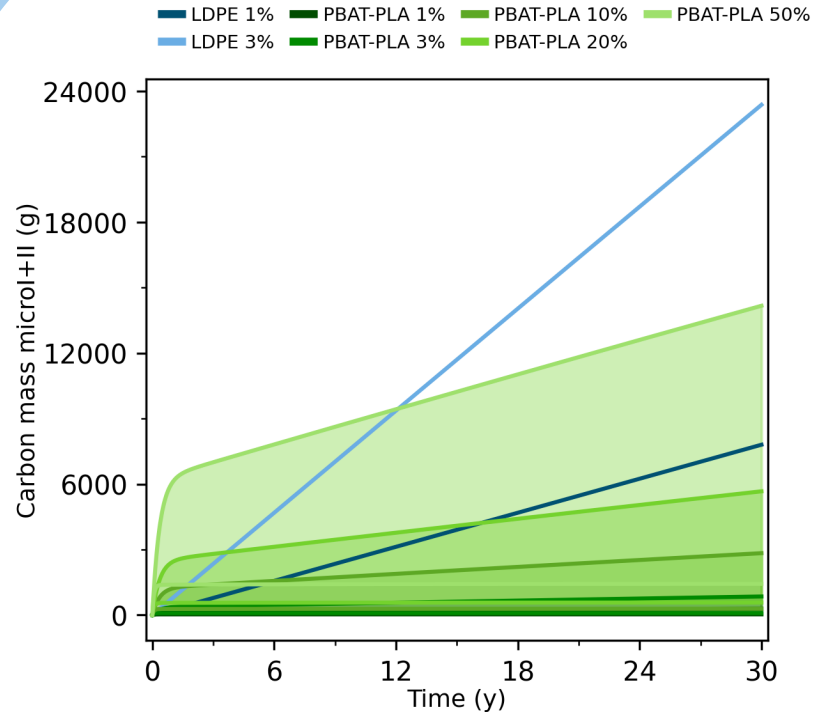
What if the one of the candy wrapper types has a **higher littering rates**?

- Littering rate: 0.2% or 3.5%

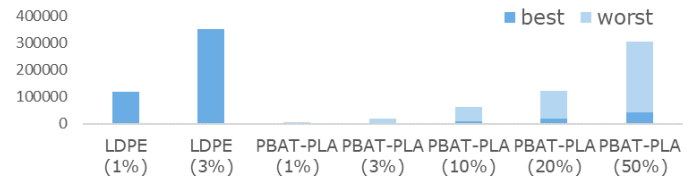


Case: Candy Wrapper

What if we **exacerbate** the littering rates?



Microplastic exposure
(time-integrated mass)



Case: Mulch film

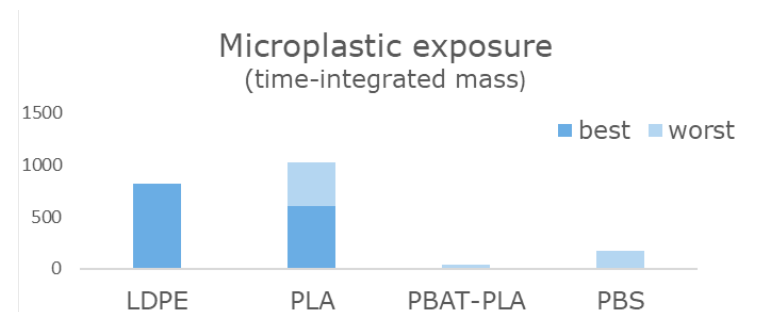
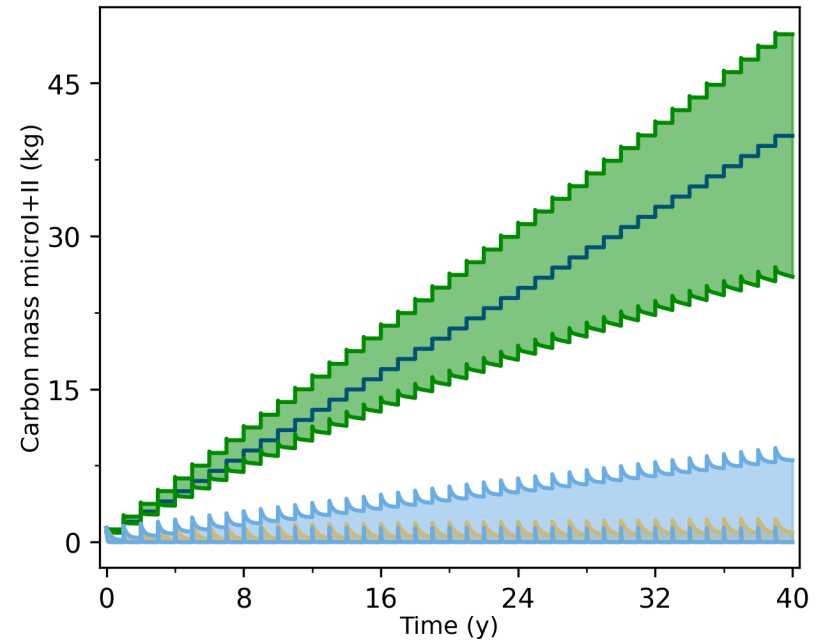
Goal:

- To compare material options for a mulch film

Functional Unit:

- The seasonal use of mulch film
- To soil environment
- All polymers are recovered (95%)

■ LDPE 1 kg/y ■ PLA 1.4 kg/y ■ PBAT-PLA 1.4 kg/y ■ PBS 1.4 kg/y



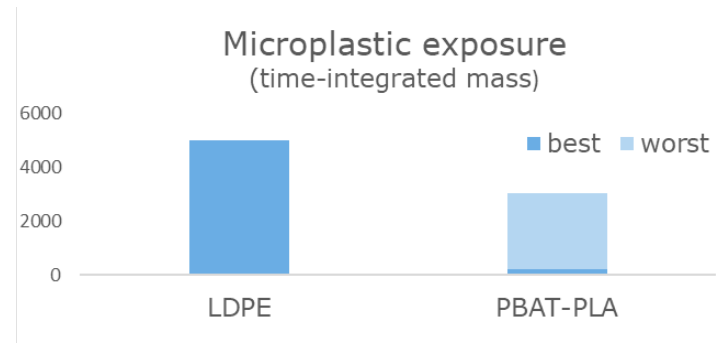
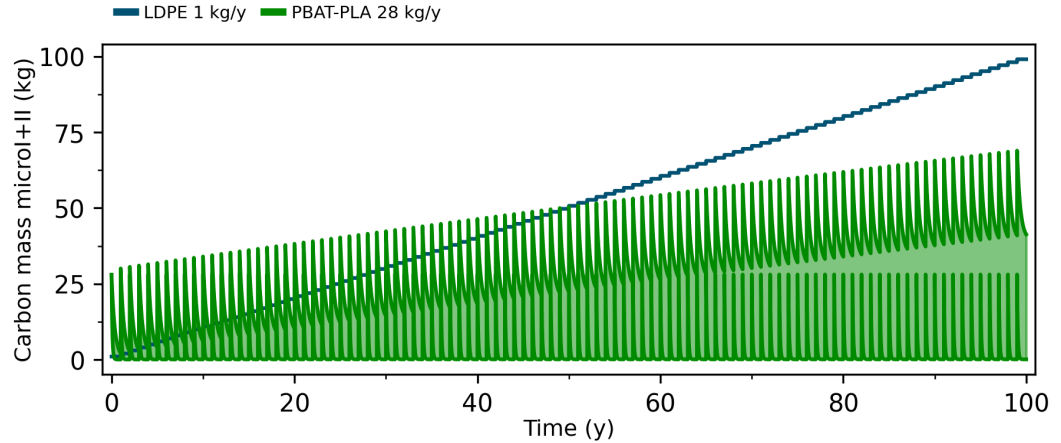
Case: Mulch film

What if the mulch films made from biodegradable polymers are **left on the land**?

Recovery rates:

LDPE: 95%

PBAT-PLA: 0%

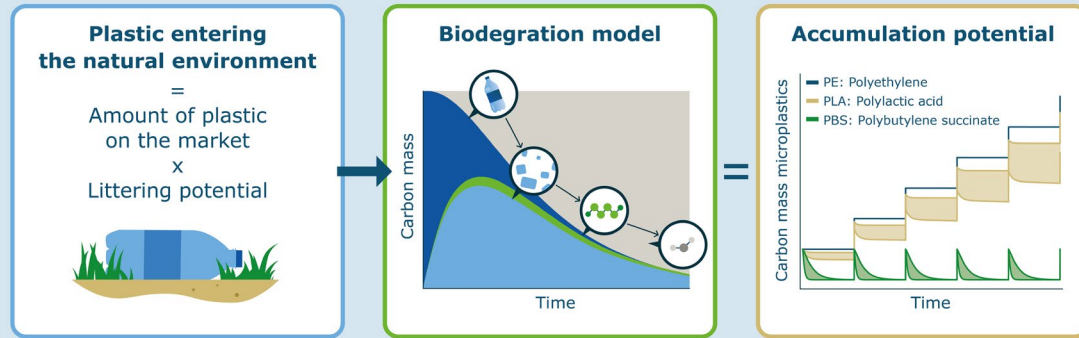


Conclusions

Predictive model of microplastic accumulation and exposure, suitable for:

- **very different** degradation properties
- **assessing scenarios** of plastic use and leakage to the environment
- determining **required biodegradation behaviour** for specific products / applications
- input in **LCA studies**

The accumulation of microplastics in the natural environment



Thanks

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Netherlands Ministry of Infrastructure and Water (5000005762) & Wageningen University & Research Knowledge Base Programme KB34 "Circular & Climate Neutral Society" (KB-34-003-006) that is supported by financing from the Dutch Ministry of Agriculture, Fisheries, Food security and Nature.

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