

# Predictive modelling to assess the accumulation of biodegradable and non-biodegradable microplastics in the natural environment

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# Sustainable Plastics Technology group

- Over 30 years of experience in biobased plastics, biodegradation and recycling
- Demonstrating the viability of alternative solutions for fossil based plastic products
- Developing plastic materials and products from sustainable sourcing to end-of-life
- Processing plastics from 0.1 kg scale up to 500 kg scale mimicking industrial scale
- Wide range of plastic analysis to support material and product development



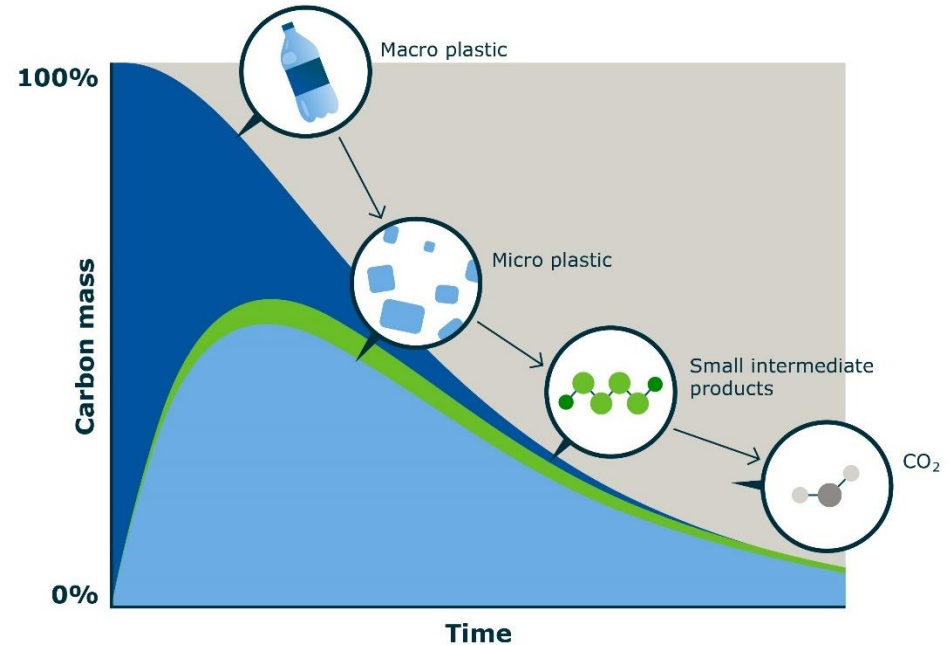
# Background

- 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 CO<sub>2</sub> 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
- Biodegradation leads to significantly lower accumulation potential

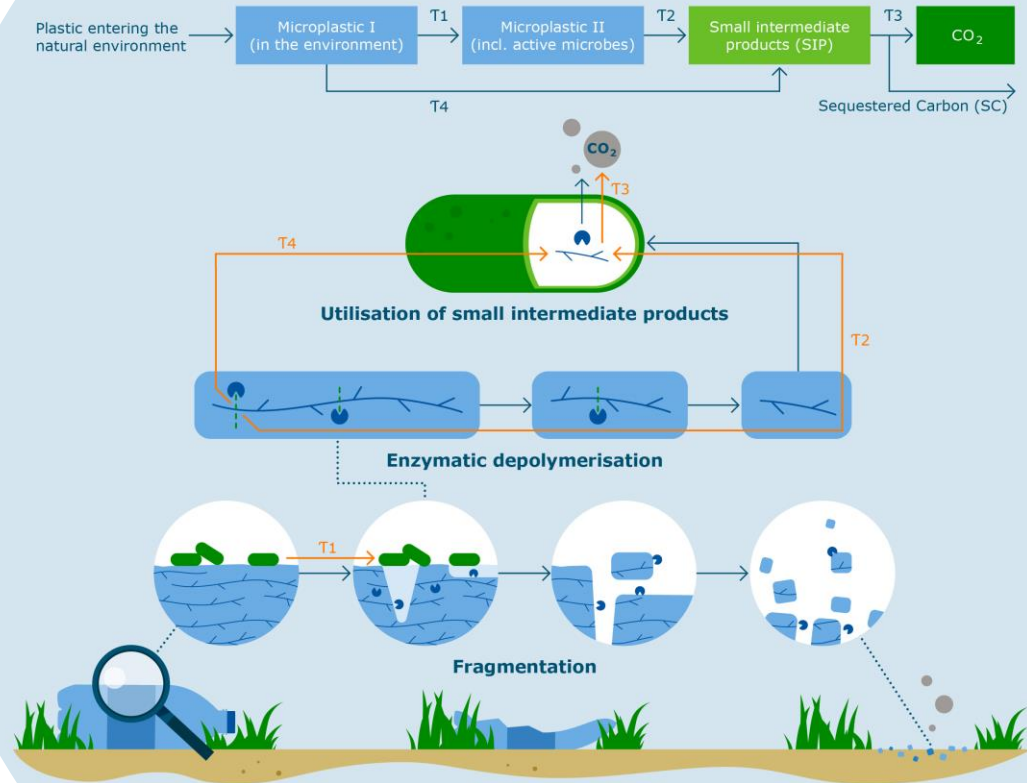
### GRAPHICAL ABSTRACT

#### 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)

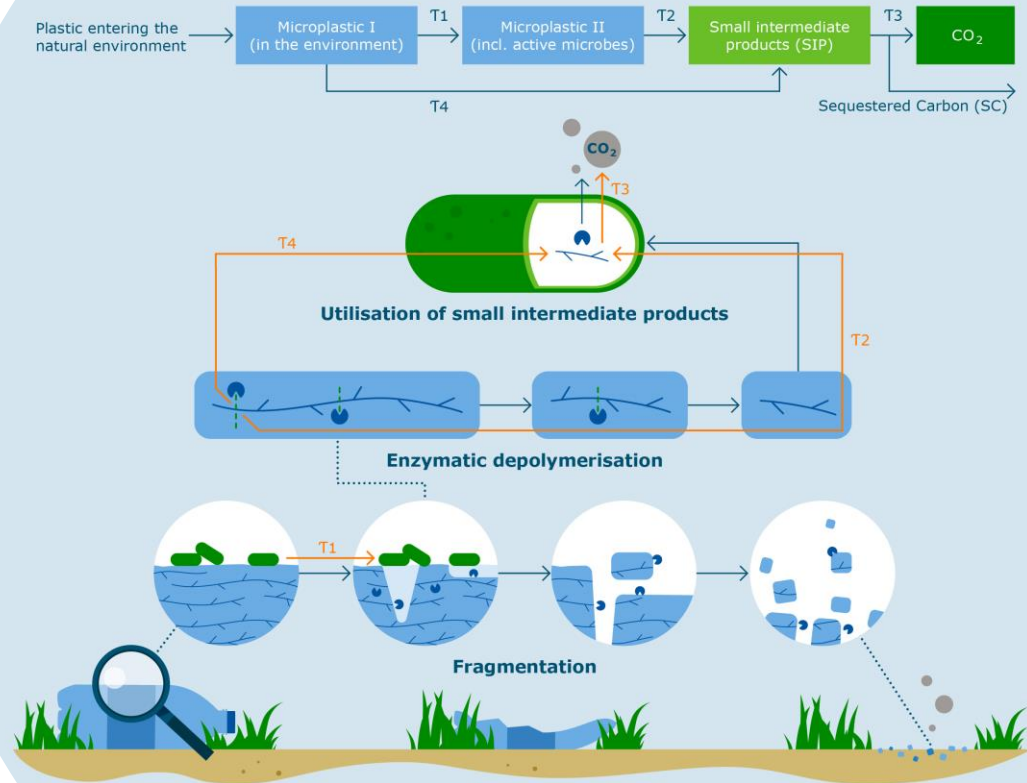


# Application

## 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				
	aqueous	aerobic	compost	marine	soil
CA	4	no data	2	2	
CP	3	no data	no data	no data	
Cellulose	no data	1	no data	7	
HDPE	no fit	no data	no data	no data	
LDPE	no data	no data	2	1	
P3H4HB	no data	no data	6	1	
PA4	no data	no data	1	no data	
PBAT	1	no fit	1	no data	
PBAT (unknown)	no data	no data	no data	1	
PBAT-PBS	no data	1	no data	no data	
PBAT-PBSeT	no data	no data	1	no data	
PBAT-PBSeT-PLA	no data	no data	2	no data	
PBAT-PLA	no fit	1	3	2	
PBAT-RF	no data	no fit	no data	no data	
PBS	1	no data	1	3	
PBSA	1	1	1	2	
PBSA-starch	no data	no data	no data	3	
PBSe	no data	no data	4	5	
PBSeT	no data	no data	4	2	
PCL	1	no data	3	no fit	
PET	1	1	no fit	no fit	
PET-cotton	2	no data	1	1	
PGA	no data	no data	1	no data	
PGA-PBAT	no data	no data	2	no data	
PHA (unknown)	no data	no data	no data	3	
PHB	2	no data	3	2	
PHB-PBAT	no data	no data	no data	1	
PHBV	2	2	1	1	
PLA	no data	3	1	3	
PLA-PCL	no data	no data	no data	2	
PLA-PHBV	no data	1	no data	no data	
PLLA	no fit	no data	no data	no data	
PVA	no data	no data	no data	1	
Polyester-2,18	no data	1	no data	no data	
cotton	3	no data	2	2	
lyocell	no data	no data	1	no data	
modal	no data	no data	1	no data	
rayon	1	no data	no fit	no data	
starch-polyesters	no data	no data	no data	4	
viscose	1	no data	1	no data	

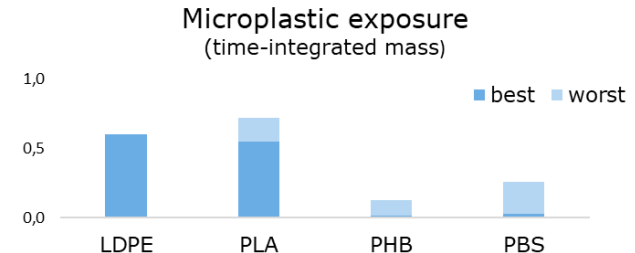
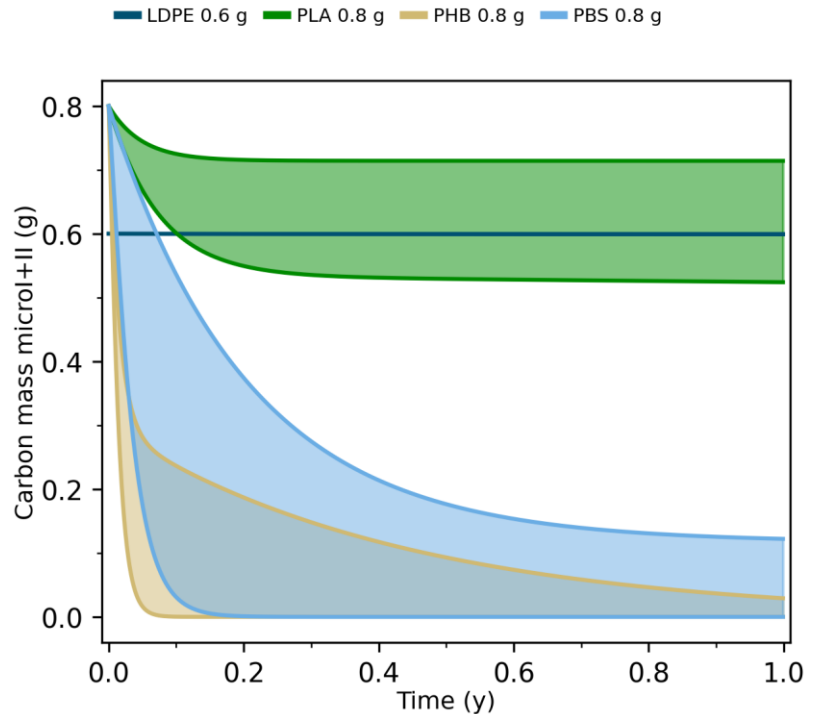
# Case: Candy Wrapper

## Goal:

- Compare material options for a candy wrapper

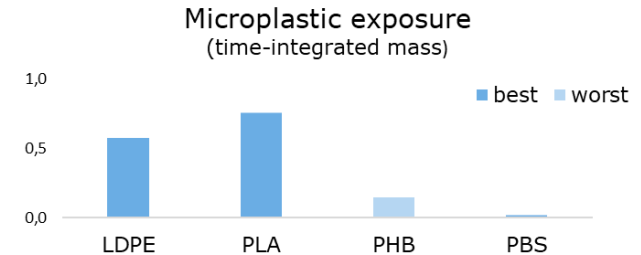
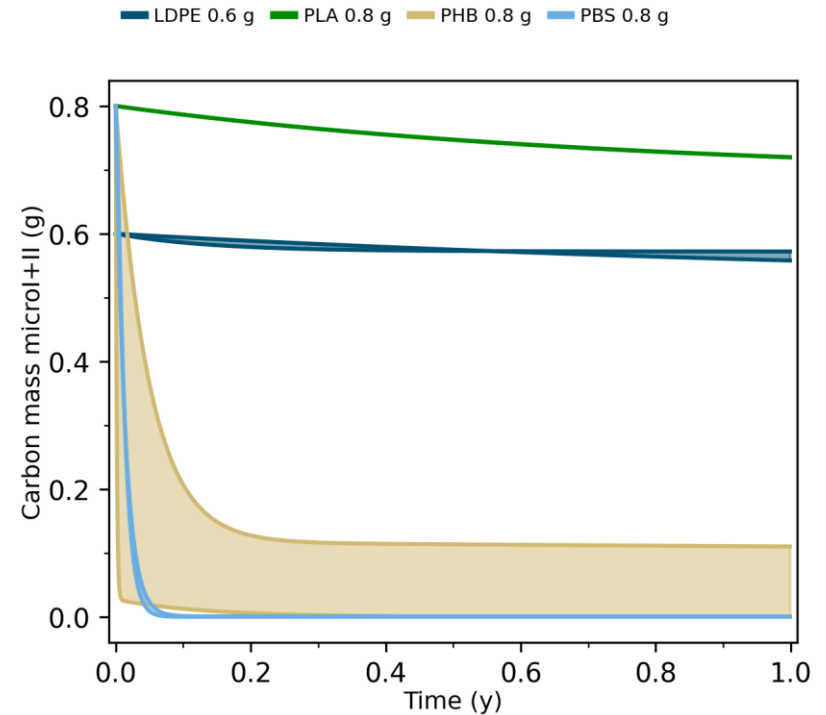
## Functional Unit:

- Littering of 1 candy wrapper
- To soil environment



# Case: Candy Wrapper

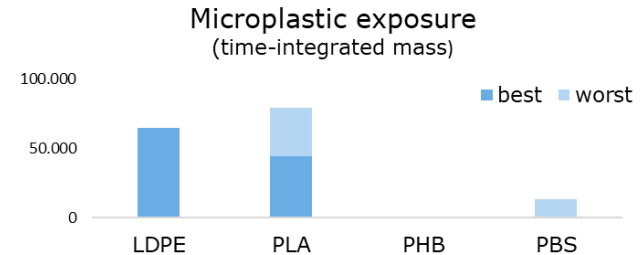
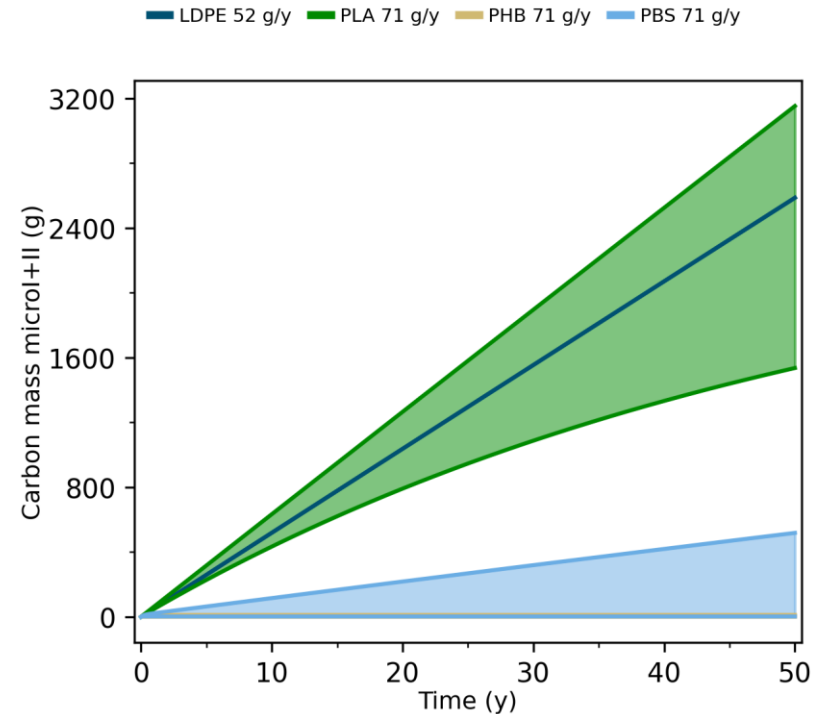
What if these wrappers end up in a **marine environment**?



# Case: Candy Wrapper

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

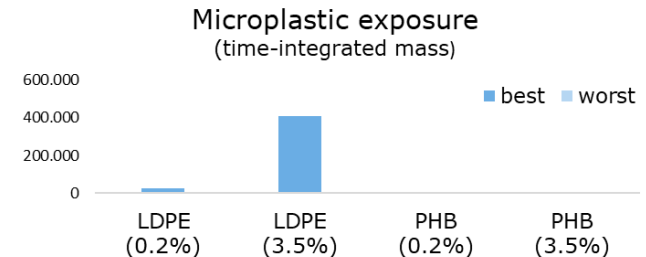
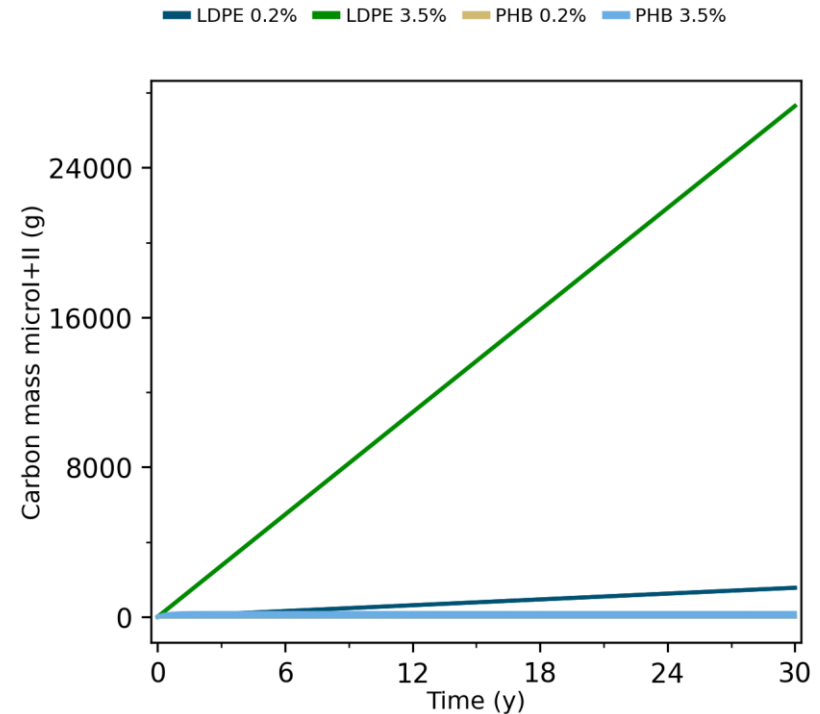
- 45 million wrappers used per year in NL
- Littering rate of 0.2%



# Case: Candy Wrapper

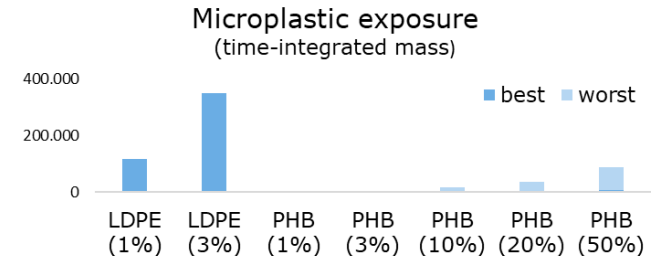
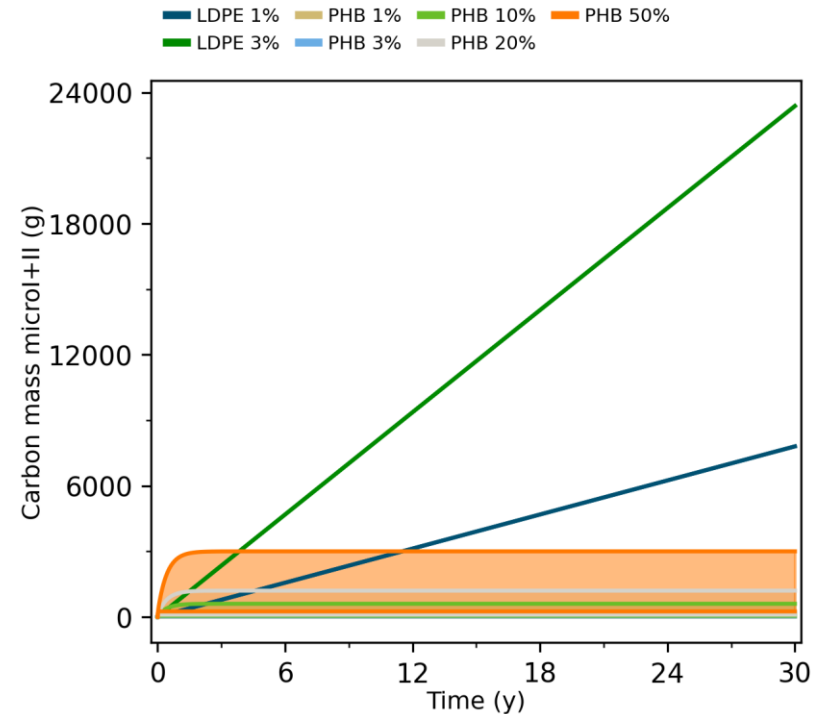
What if one of the candy wrapper types has a **higher littering rates**?

- Littering rate:  
0.2% or 3.5%



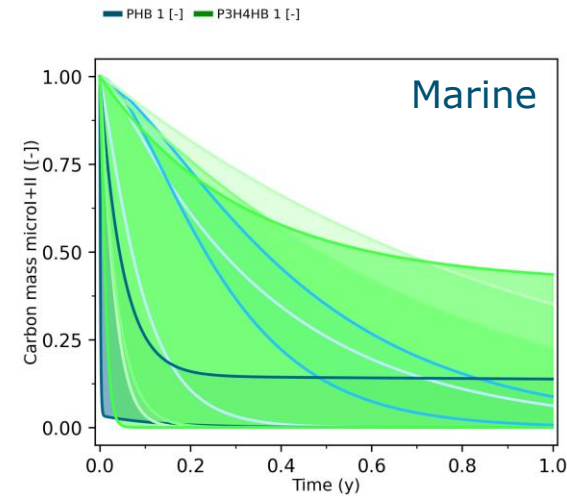
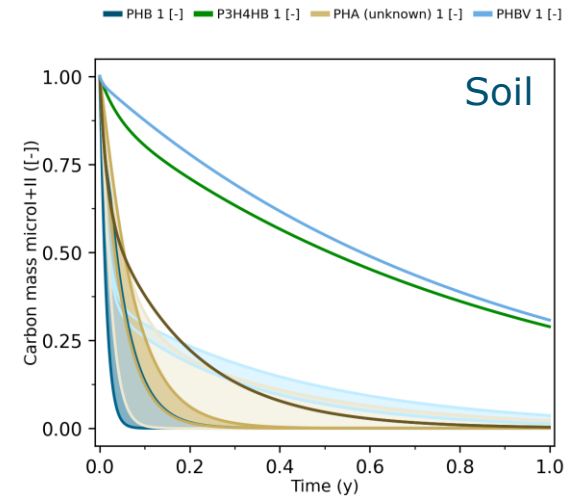
# Case: Candy Wrapper

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



# Database

- Data from literature
- Different:
  - PHA type polymers
  - Environments



# Case: Mulch film

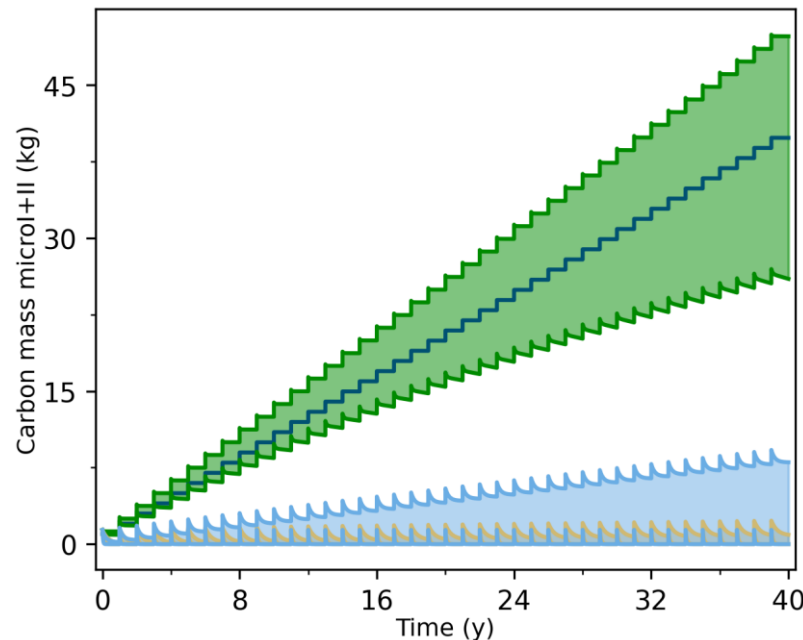
## Goal:

- To compare material options for a mulch film

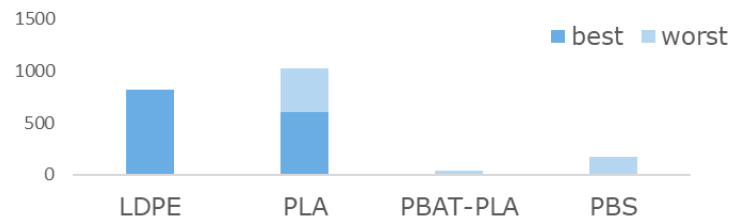
## Functional Unit:

- 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



Microplastic exposure  
(time-integrated mass)



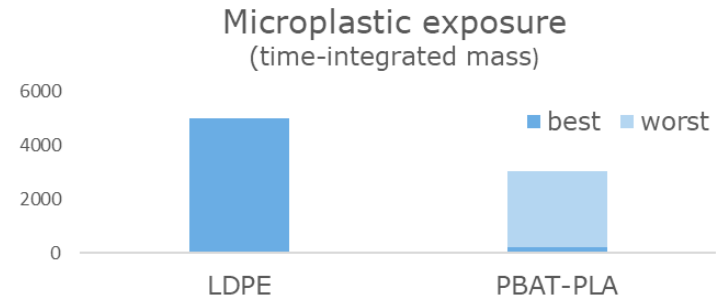
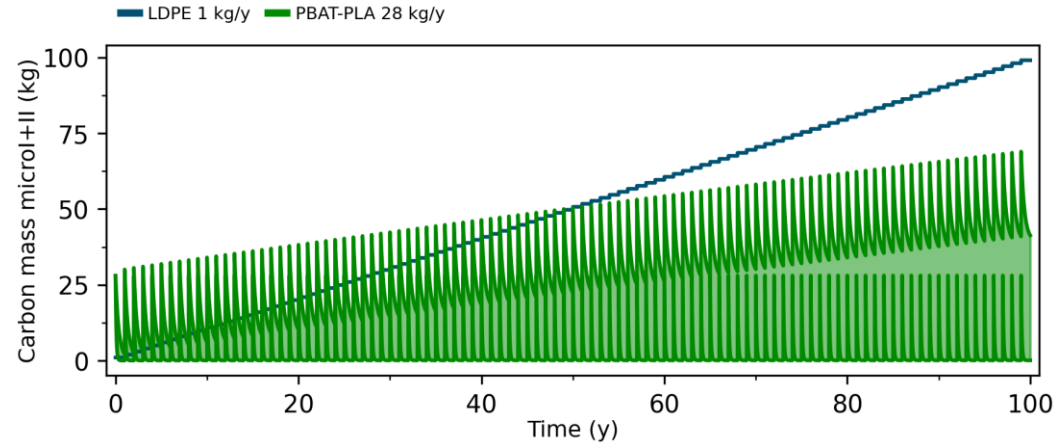
# Case: Mulch film

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

## Recovery rates:

LDPE: 95%

PBAT-PLA: 0%

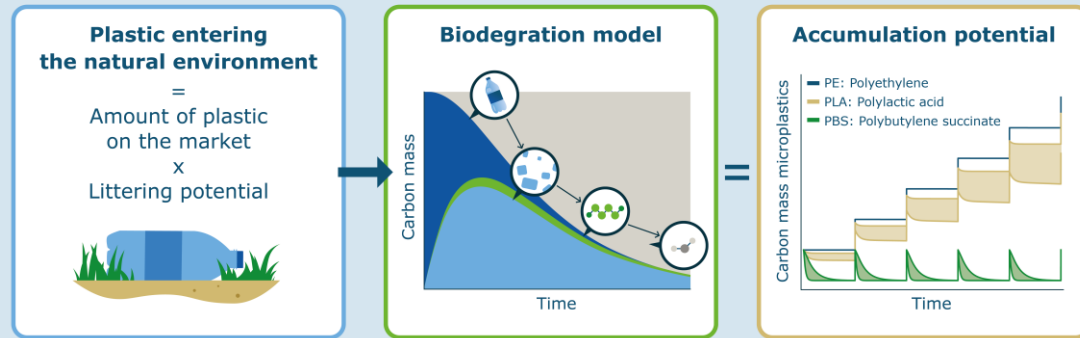


# Conclusions

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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