

# 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



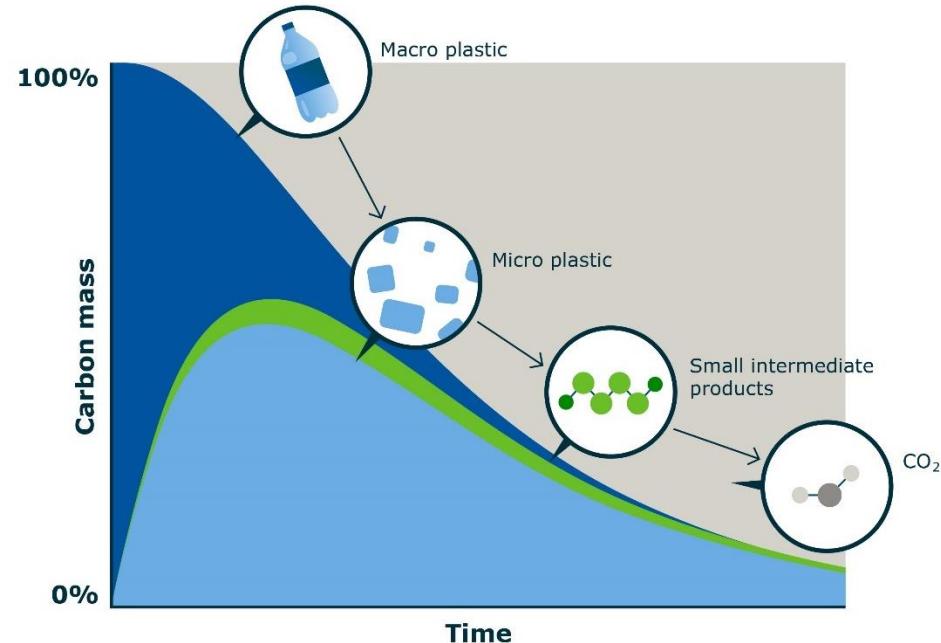
# Background

- 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  
• This ability leads to significantly higher accumulation potential

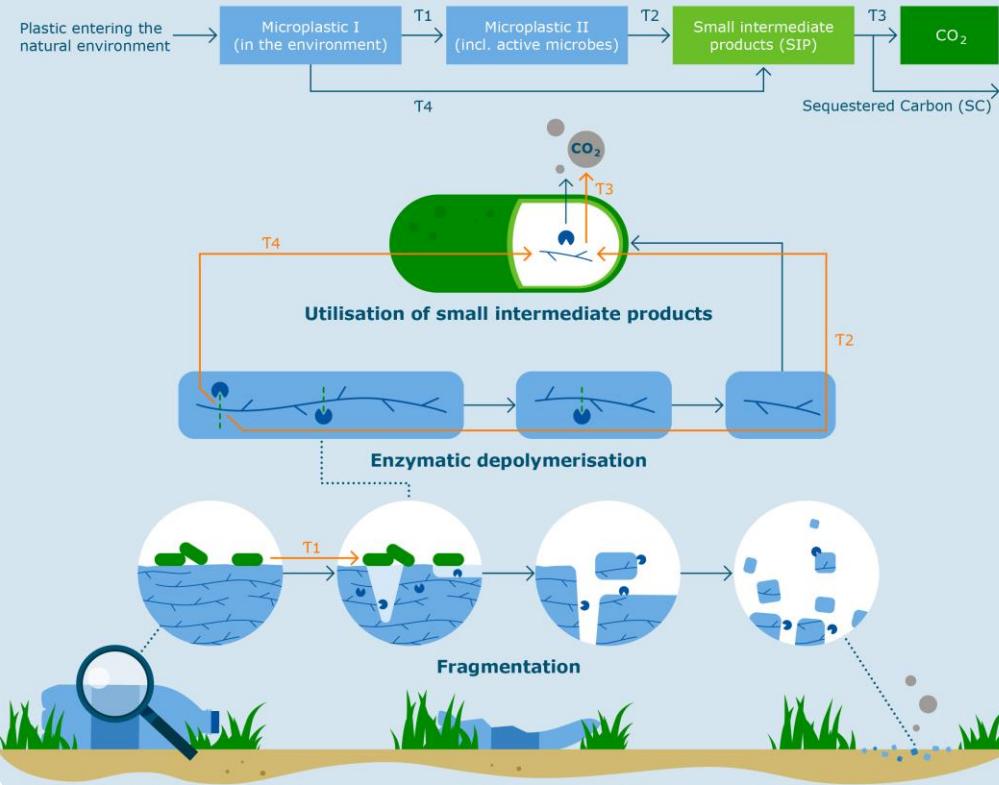
## GRAPHICAL ABSTRACT

### The accumulation

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)

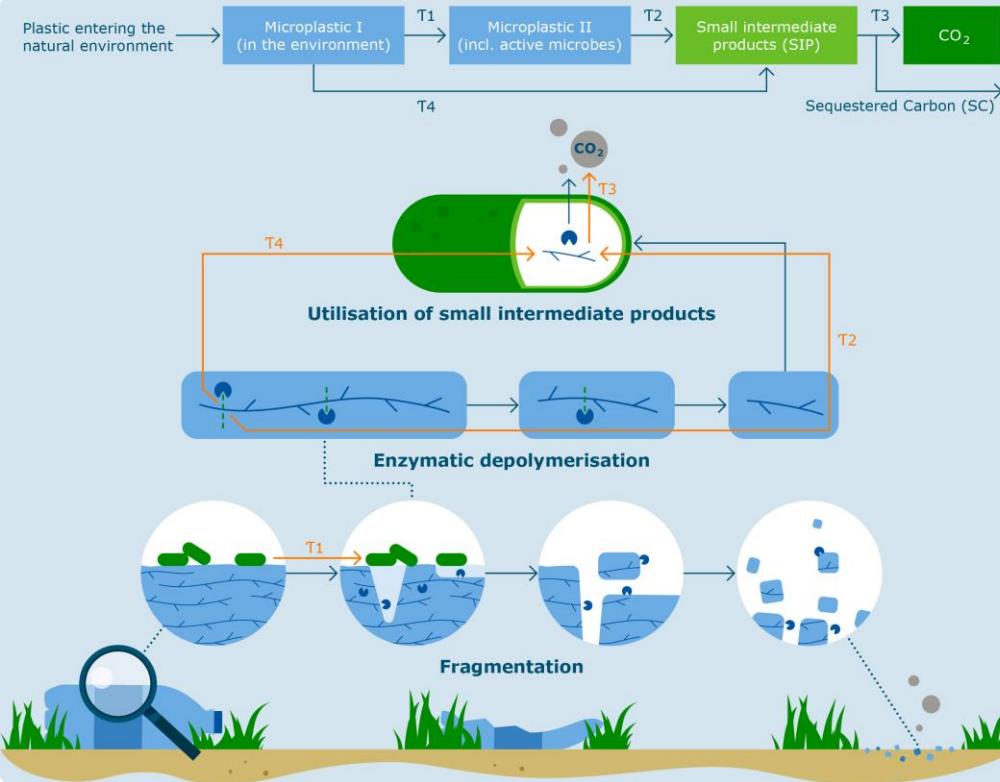


# Application

## Determine and compare:

- Accumulation potential
- Exposure to microplastics
- Continuously or seasonally

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



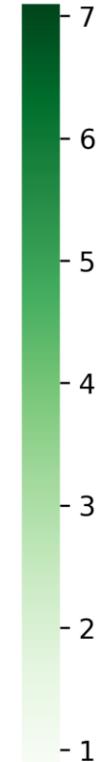
# Database

## ■ Data from literature

## ■ Different:

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

*Disclaimer: data from polymer blends have specific compositions*

A vertical color bar on the right side of the table, ranging from dark green at the bottom to dark red at the top. The scale is marked with numerical values from -1 to 7 on the right side of the bar.

Polymer	aqueous aerobic	compost	marine	soil
CA	4	2	2	2
CP	3	no data	no data	7
Cellulose	no data	1	no data	no data
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	no data	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

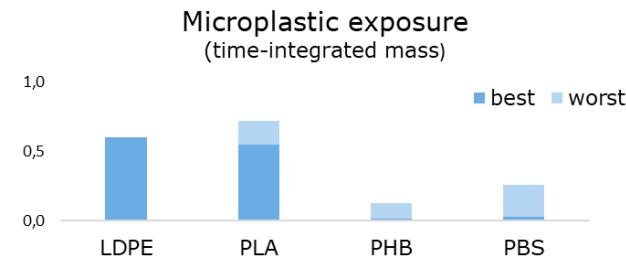
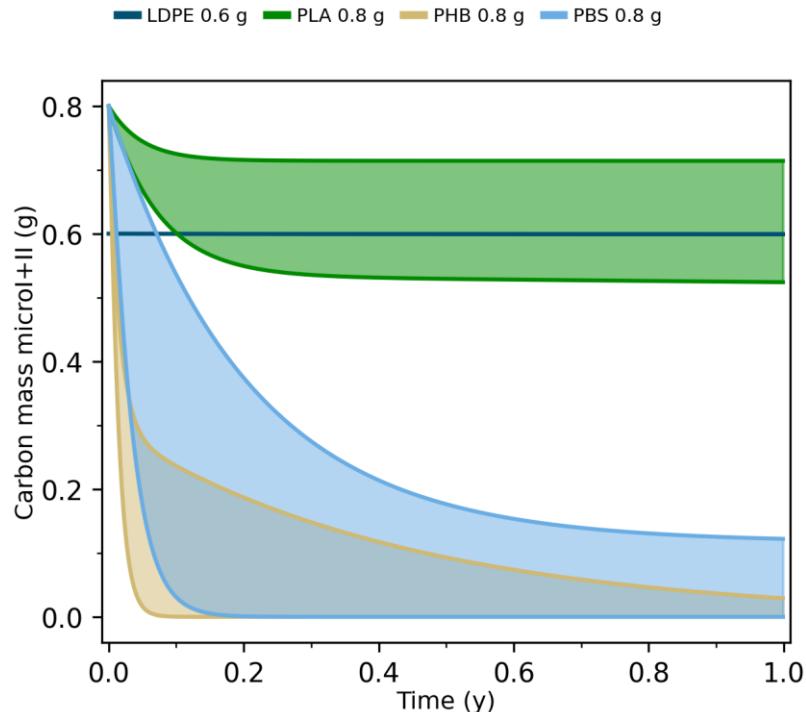
# Case: Candy Wrapper

## Goal:

- Compare material options for a candy wrapper

## Functional Unit:

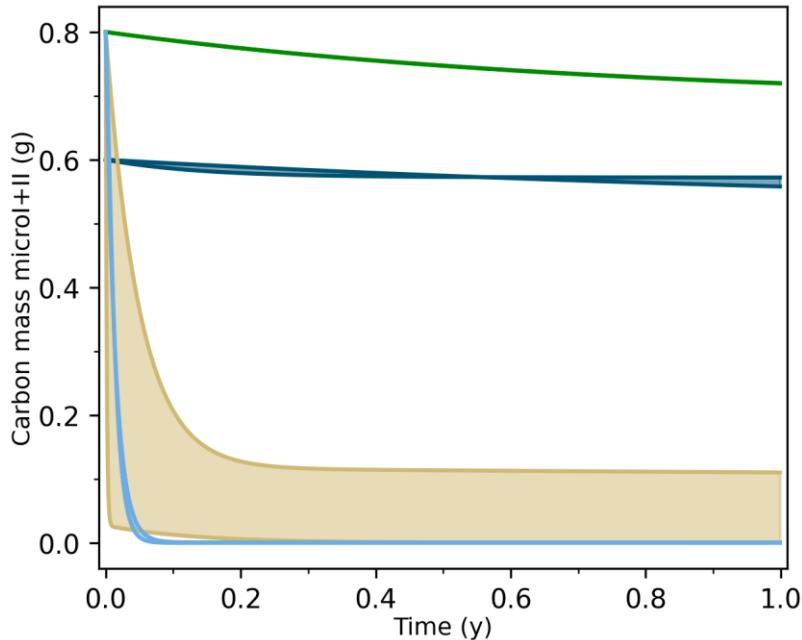
- Littering of 1 candy wrapper
- To soil environment



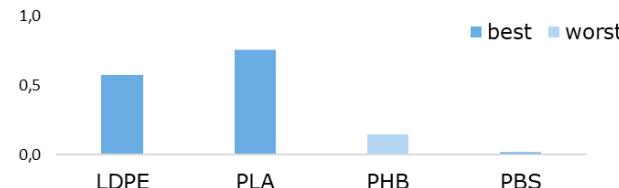
# Case: Candy Wrapper

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

LDPE 0.6 g PLA 0.8 g PHB 0.8 g PBS 0.8 g



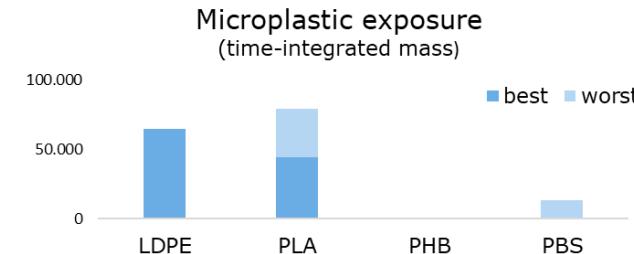
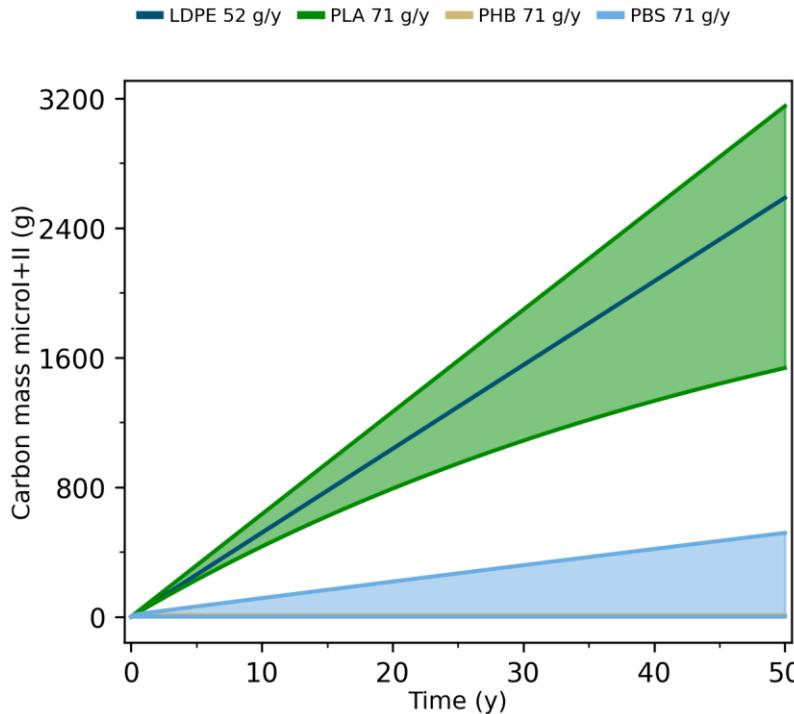
Microplastic exposure  
(time-integrated mass)



# 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%

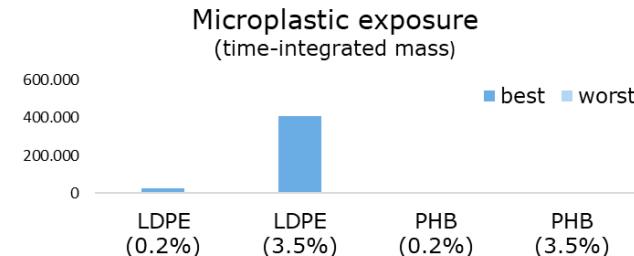
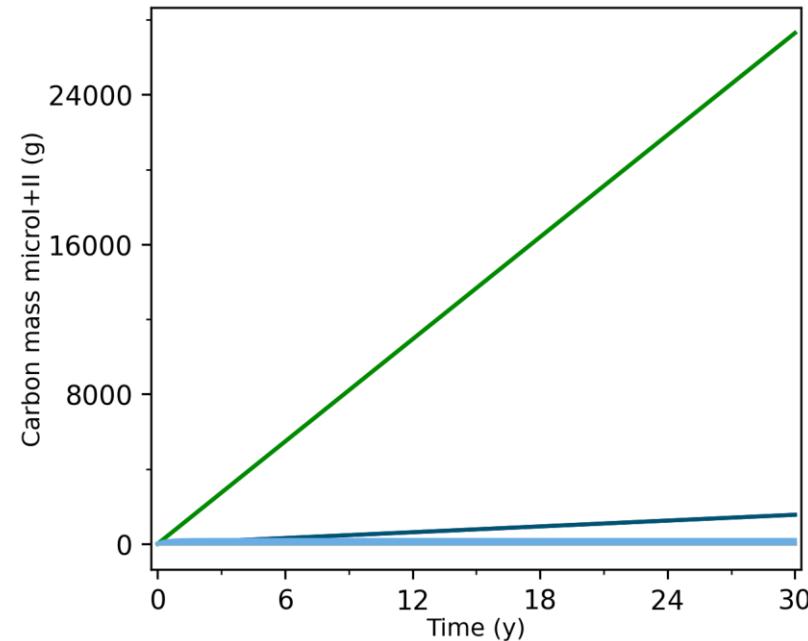


# Case: Candy Wrapper

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

- Littering rate:  
0.2% or 3.5%

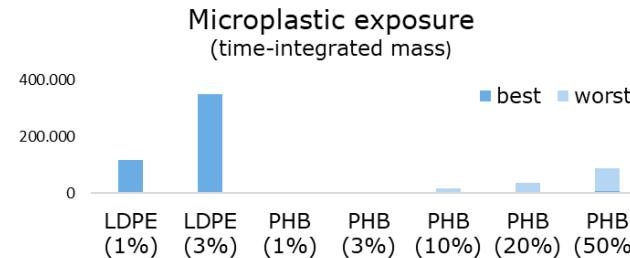
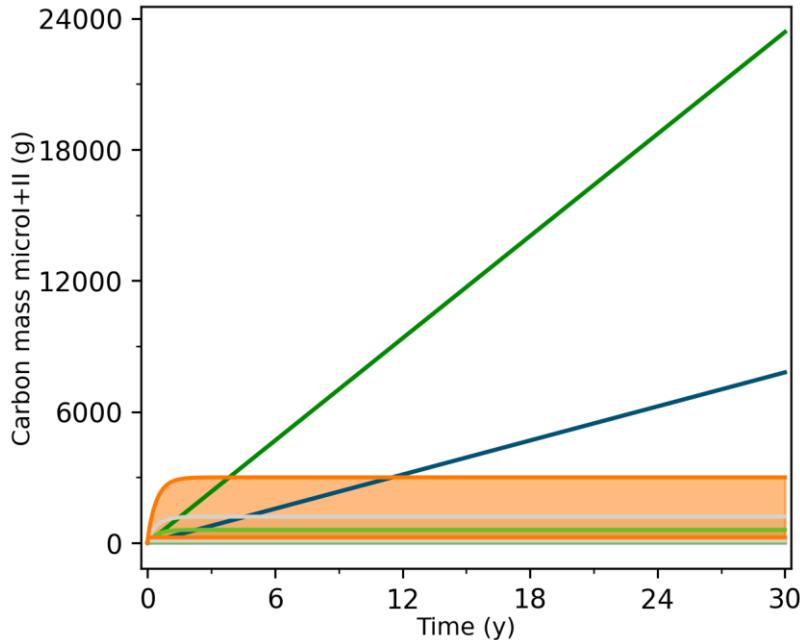
LDPE 0.2% LDPE 3.5% PHB 0.2% PHB 3.5%



# Case: Candy Wrapper

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

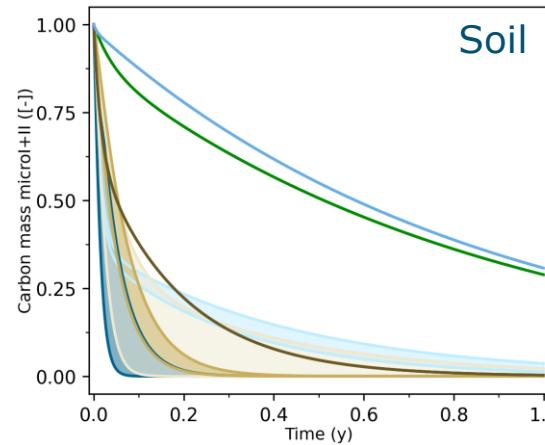
LDPE 1% LDPE 3% PHB 1% PHB 3% PHB 10% PHB 20% PHB 50%



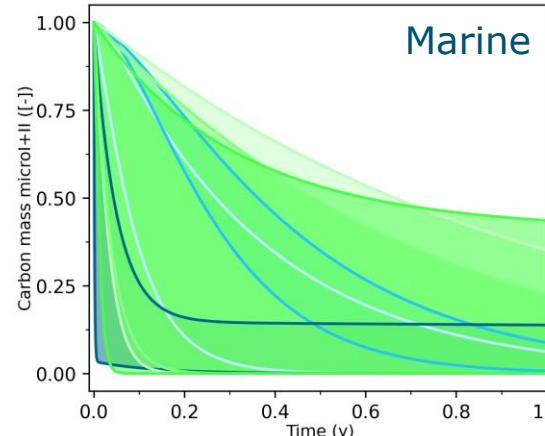
# Database

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

PHB 1 [-] P3H4HB 1 [-] PHA (unknown) 1 [-] PHBV 1 [-]



PHB 1 [-] P3H4HB 1 [-]



# Case: Mulch film

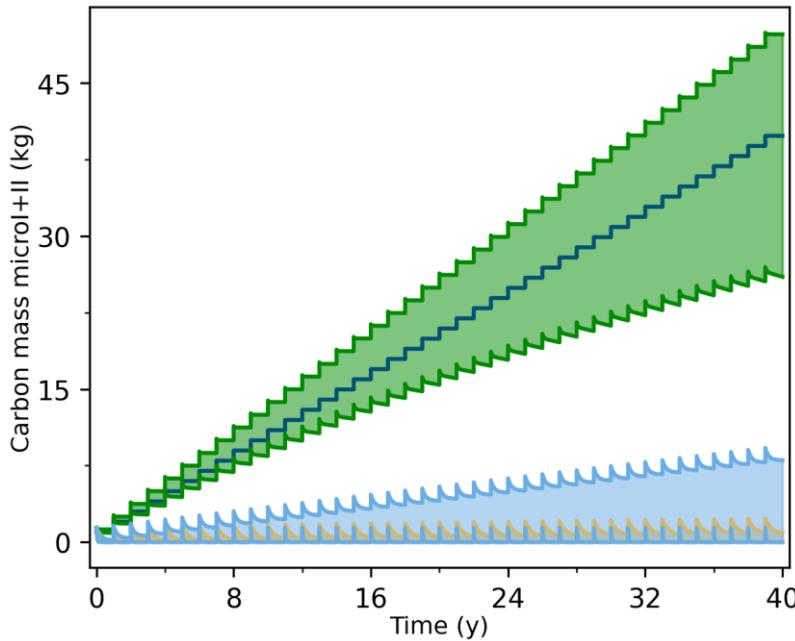
## Goal:

- To compare material options for a mulch film

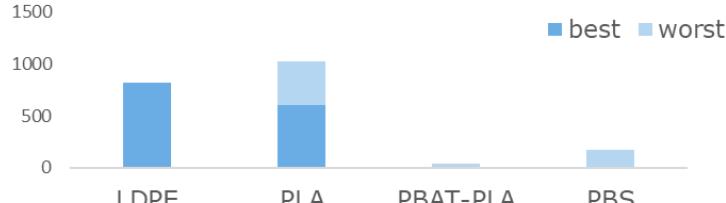
## Functional Unit:

- 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)



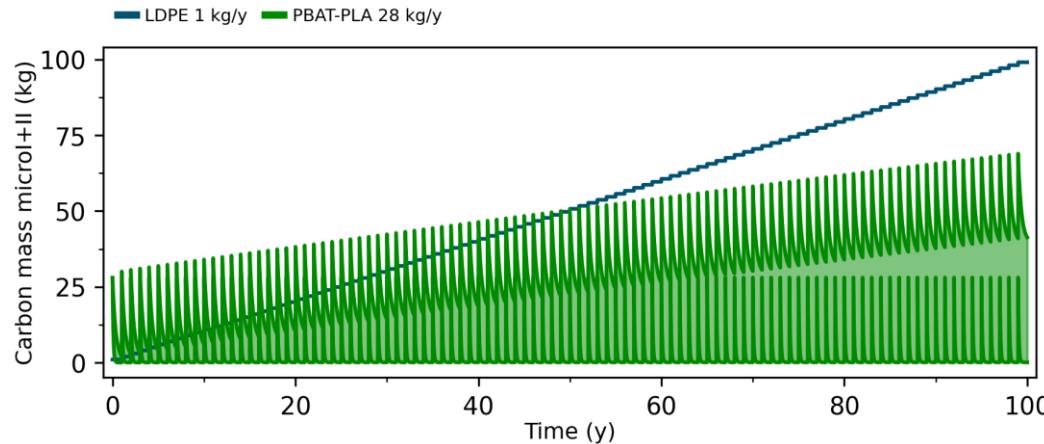
# Case: Mulch film

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

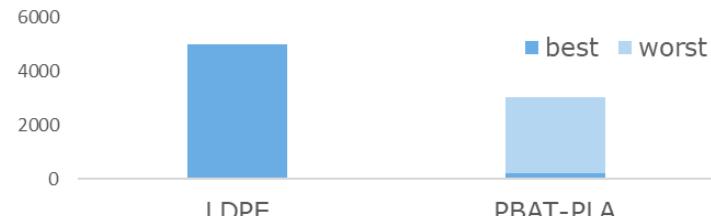
## Recovery rates:

LPPE: 95%

PBAT-PLA: 0%



Microplastic exposure  
(time-integrated mass)



# 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**

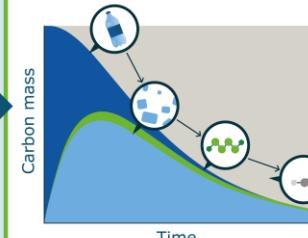
## The accumulation of microplastics in the natural environment

### Plastic entering the natural environment

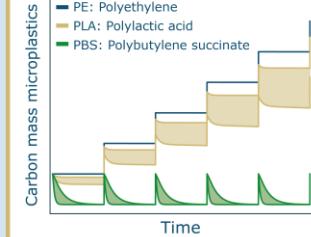
$$= \text{Amount of plastic on the market} \times \text{Littering potential}$$



### Biodegradation model



### Accumulation potential



# Thanks

## Funding:

National Growth Fund “BioBased Circular” that is supported by the Netherlands Ministry of Climate Policy and Green Growth (ref. NGFBBC2405)

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