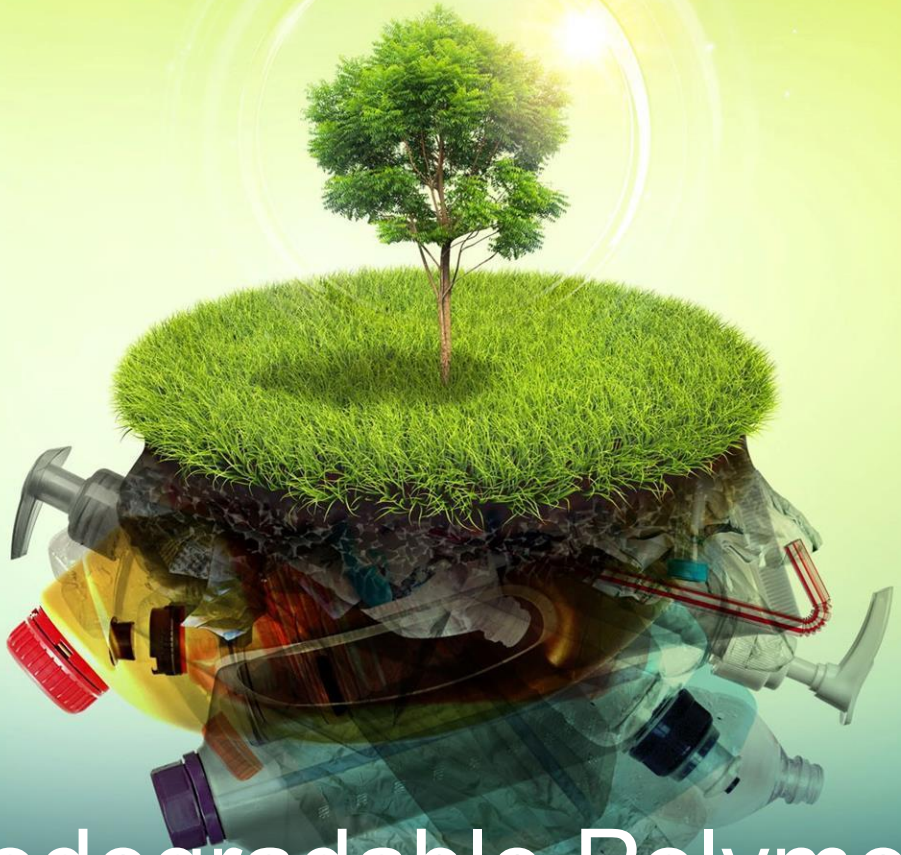


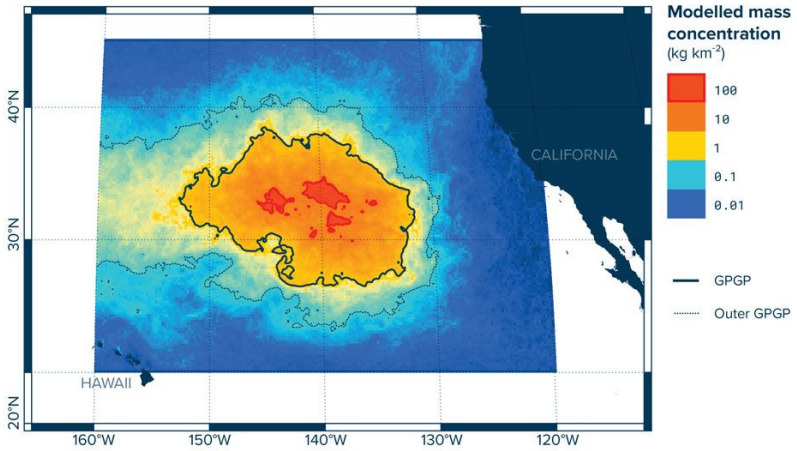
Biodegradable Polymers

John Harrold - September 2022 - HEJC

Biodegradable Polymers

Modern plastics have been used for the past 115 years. From that time forward they have revolutionized people's lives and how they interact with the world. However, at that same time, these plastics have been accumulating in landfills and in the environment. Much like the introduction of plastics promised to free consumers from using materials like ivory, biodegradable plastics promise to free consumers from the need to add to that plastic accumulation. This accumulation is as vast as the great pacific garbage patch to the Citarum River in West Java Indonesia, and as intrusive as microplastics being found on the Peak of Mount Everest, the depths of the Mariana Trench, and even in a human blood sample! As a species we obviously can't contain plastics, and the fact that single use products have become ubiquitous for all walks of life, something needs to change.

The Case for biodegradable plastics



basedtweets Follow ...

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Ocean pollution is a huge problem but there is an obvious solution. Raccoons love to eat garbage. Therefore, if we trained a raccoon navy, they'd be able to go out into the sea & eat the ocean garbage. I don't see how this plan could go wrong. We should also give them swords.

9:56 AM · 9/22/22 · Twitter for iPhone

5,549 likes

basedtweets The goats

Problem Solved!

Illustration by Bryce Baker

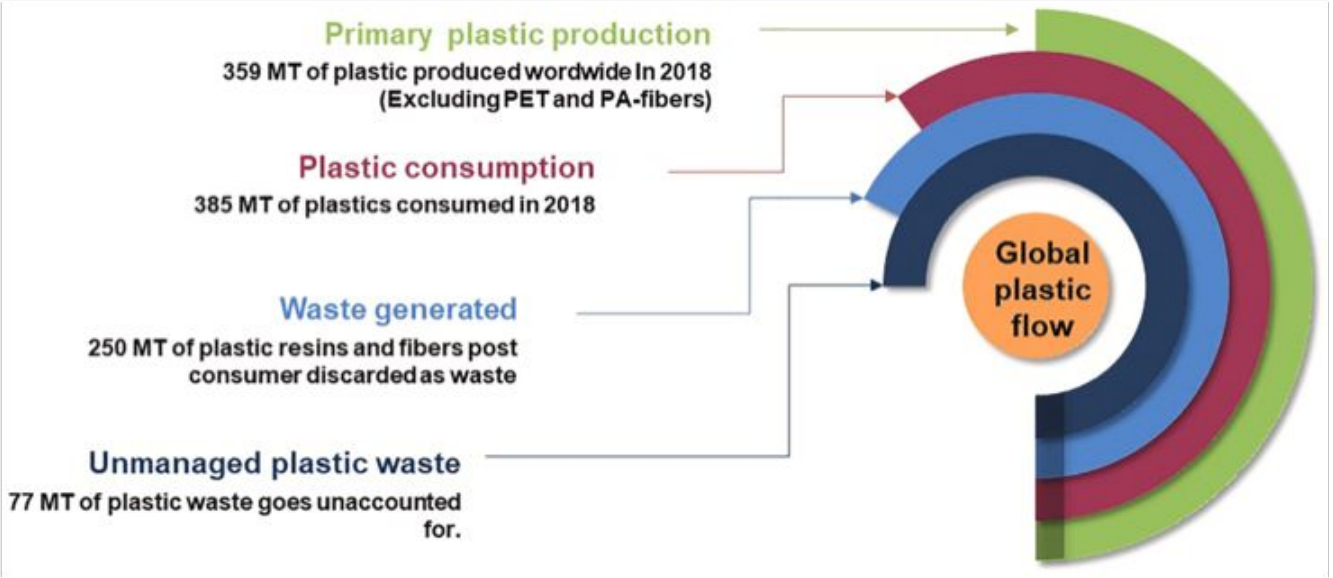
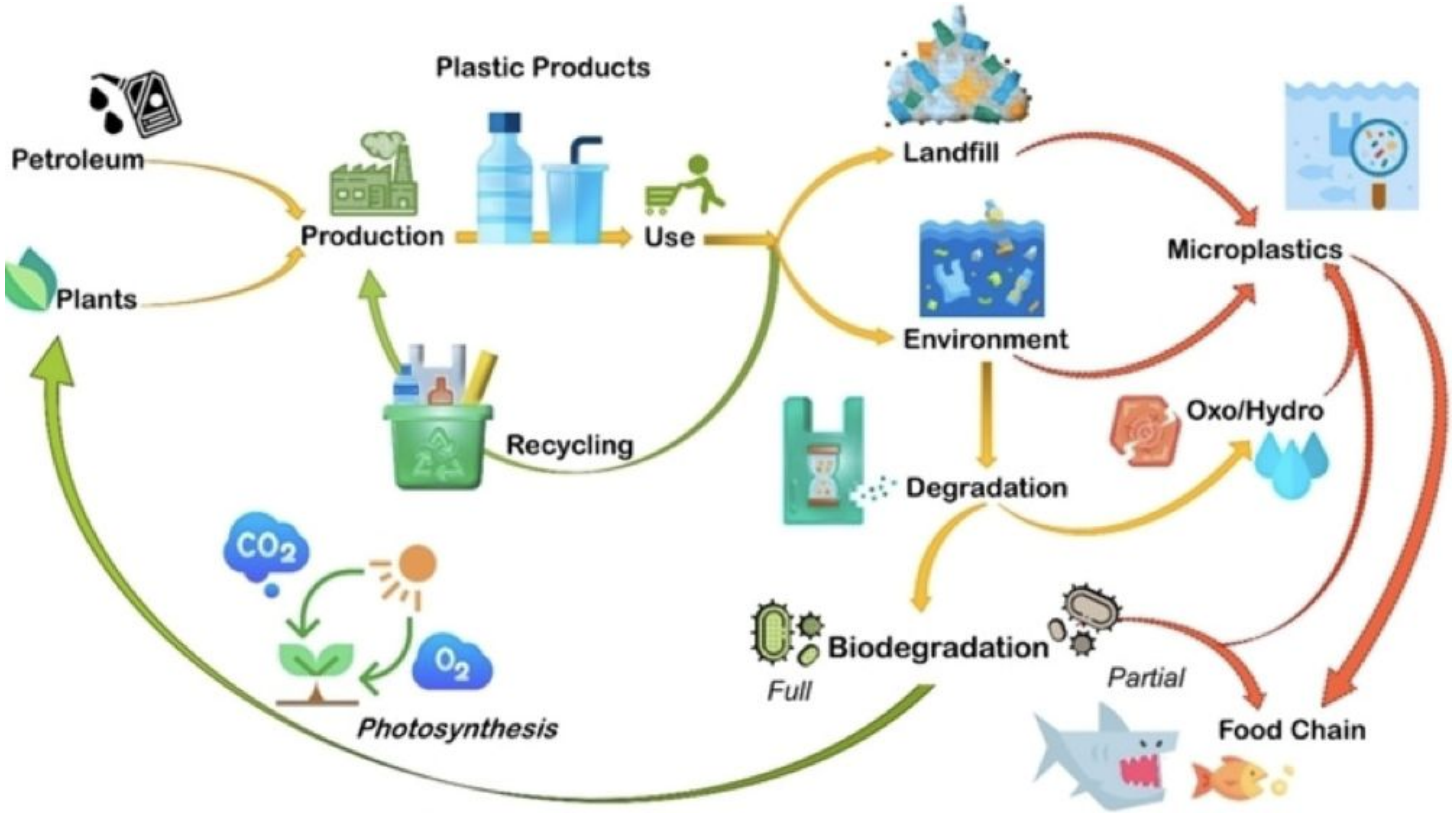


Fig. 1. Global flow of plastic material for the year 2018, including cumulative data sourced from 44 countries and regions covering 80% of global GDP.

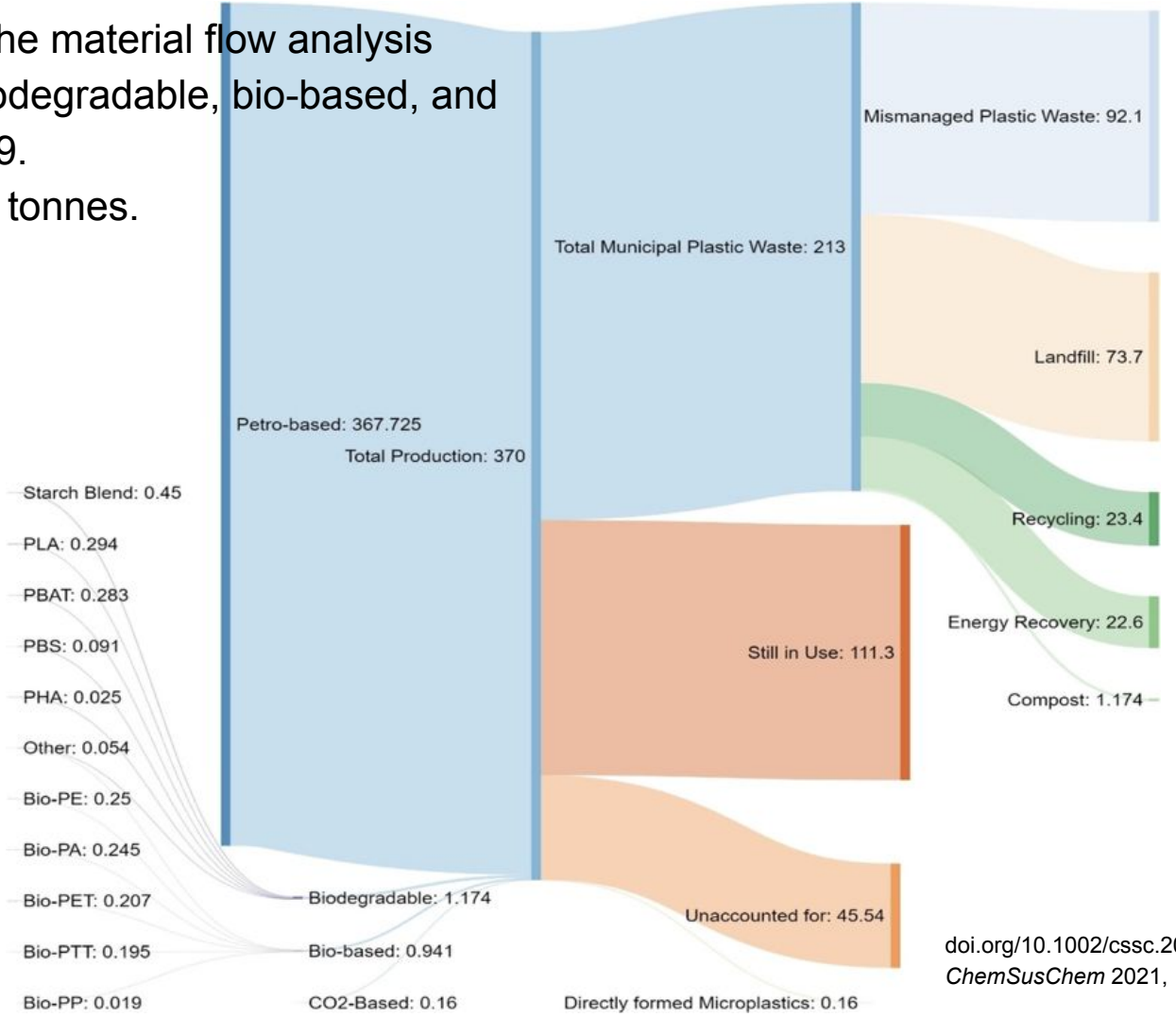
https://doi.org/10.1016/j.biortech.2021.124739
Bioresource Technology 325 (2021) 124739

Various fates for petro-based and bio-based plastics, including landfill, recycling, and environmental degradation.



doi.org/10.1002/cssc.202002044 *ChemSusChem* 2021, *14*, 56 – 72

Sankey diagram showing the material flow analysis for fossil-carbon-based, biodegradable, bio-based, and CO2-based plastics in 2019.
All values are in millions of tonnes.



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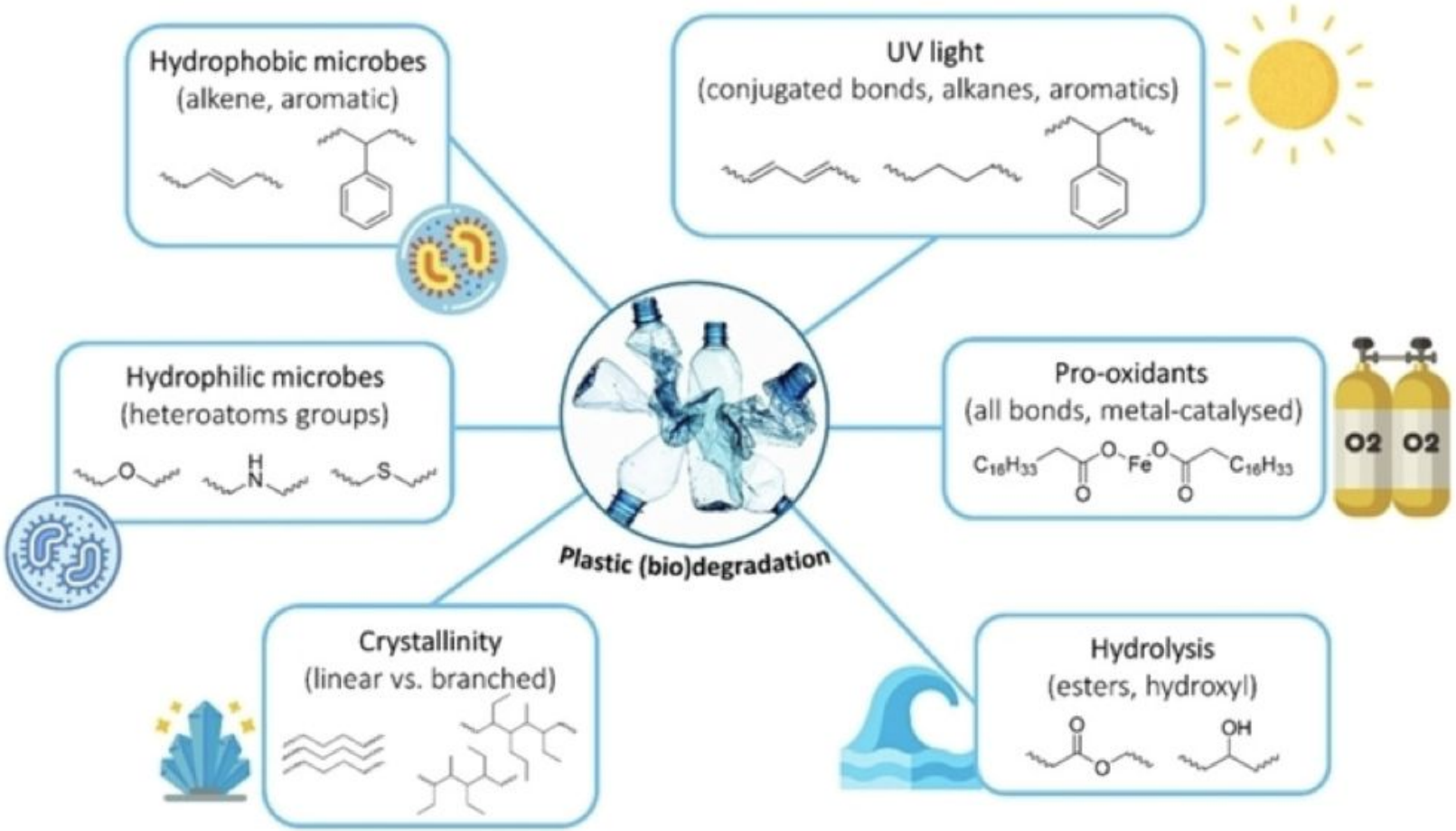
ChemSusChem 2021, *14*, 56 – 72

Key properties and processes that induce (bio)degradation of different chemical groups



doi.org/10.1002/cssc.202002044 *ChemSusChem* 2021, *14*, 56 – 72

Polymers!!!!!!!!

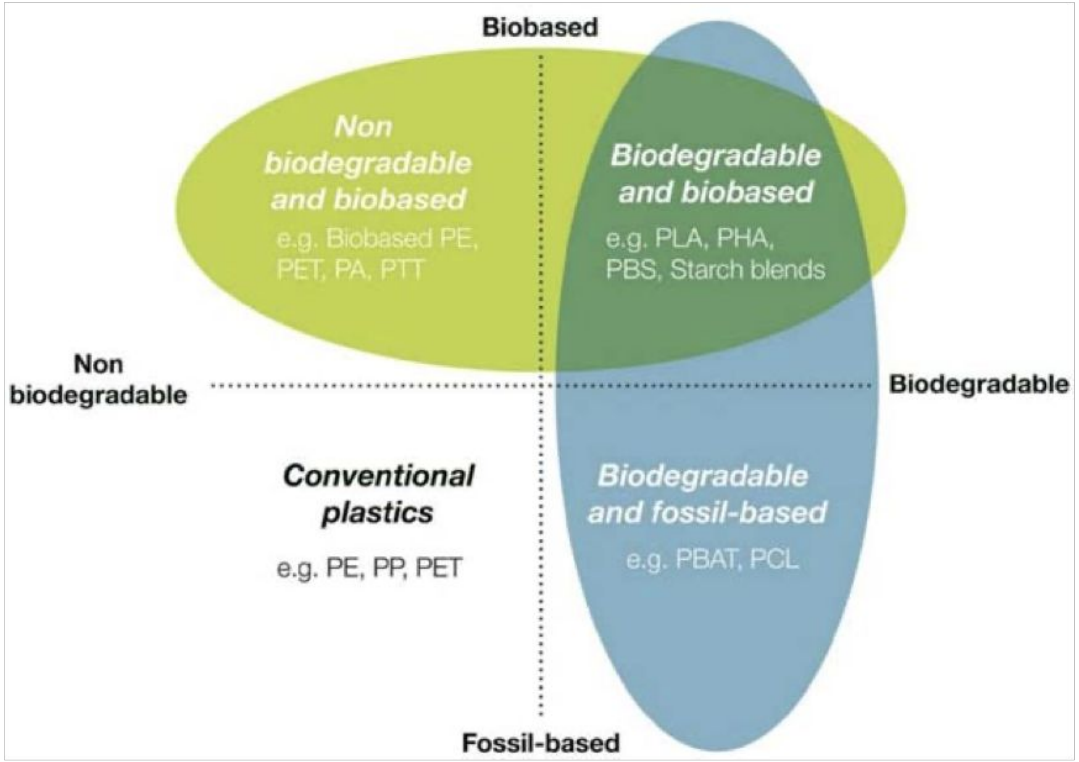
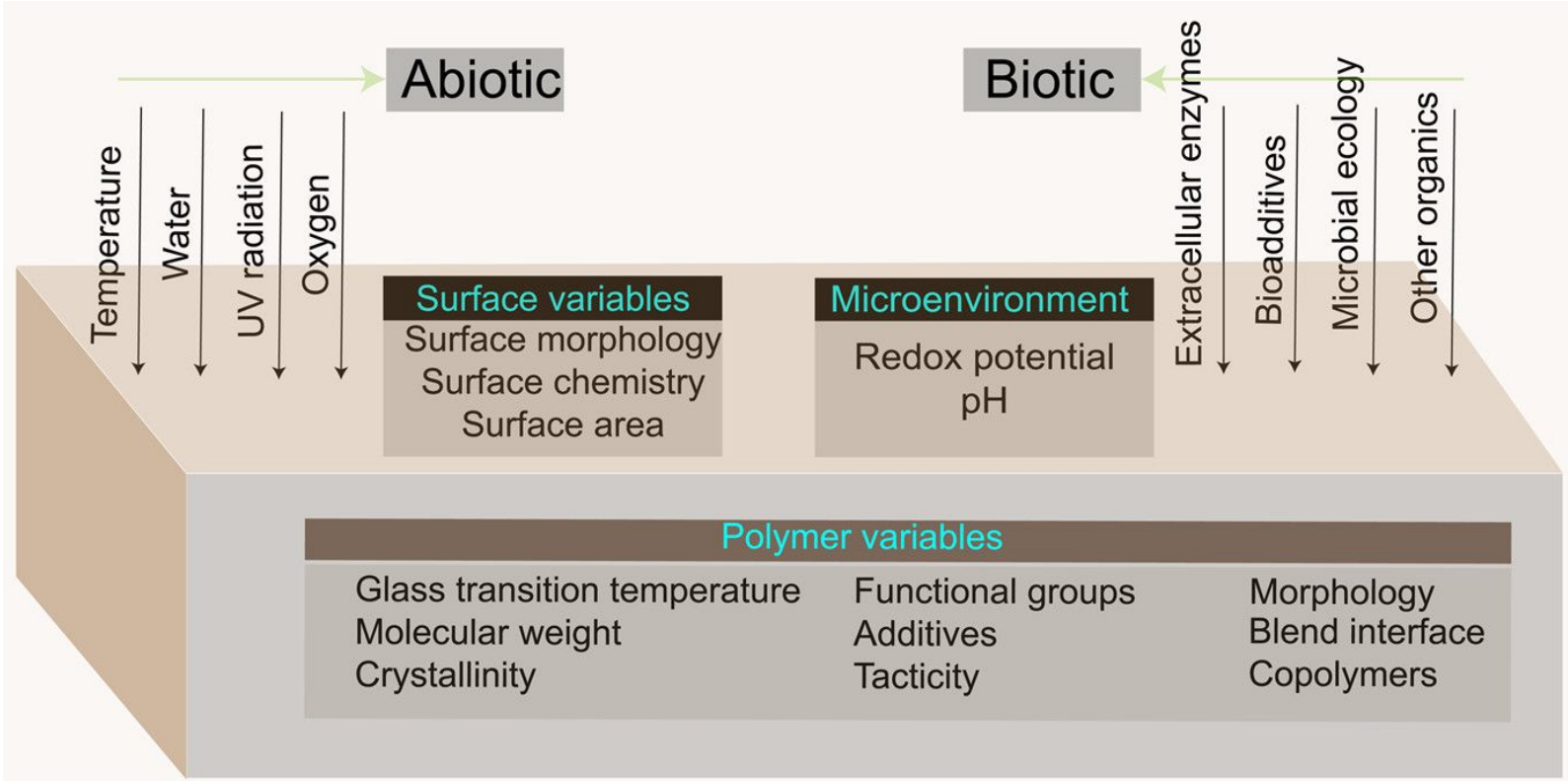


Figure 1. *Understanding the three different categories of bioplastics [23].*

PE	Polyethylene
PET	Polyethylene terephthalate
PA	Polyamine (Nylon)
HDPE	High Density Polyethylene
LDPE	Low Density Polyethylene
PLA	Polylactic acid
PHA	Polyhydroxyalkanoates
PHB	Polyhydroxybutyrate
PBS	Polybutylene succinate
PBAT	Polybutylene adipate terephthalate
PP	Polypropylene
PEF	Polyethylene furanoate
PCL	Polycaprolactone
TPS	Thermoplastic Starch

Advances in Bioscience and Bioengineering. Volume 5, Issue 4, August 2017 , pp. 63-70. doi: 10.11648/j.abb.20170504.13

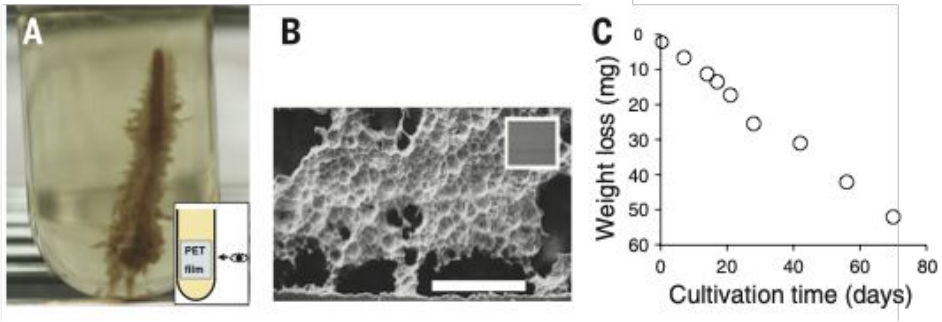
Multivariable space of biodegradation.

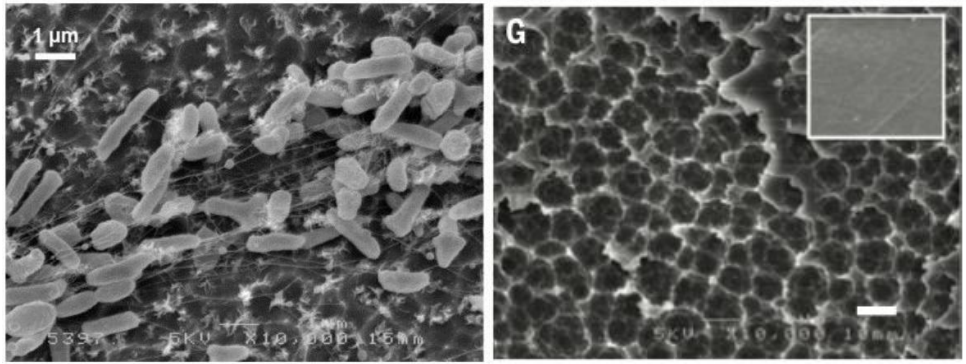


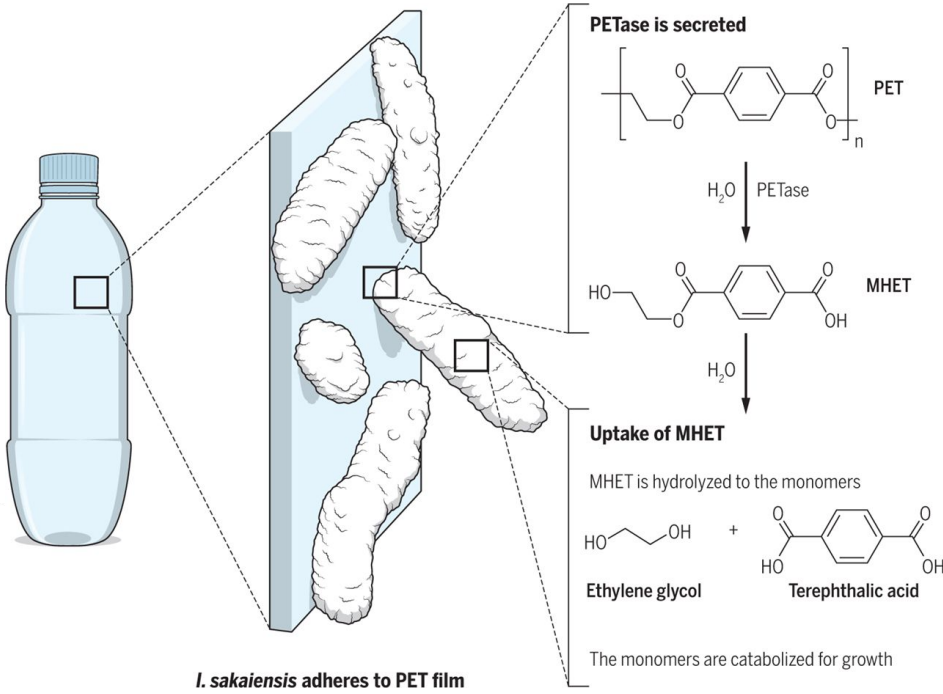
Microbe–environment–polymer dialogue is dependent on the interplay of abiotic and biotic factors.

https://doi.org/10.1021/acssuschemeng.1c00801 ACS Sustainable Chem. Eng. 2021, 9, 6170−6187

Techniques to degrade current plastics



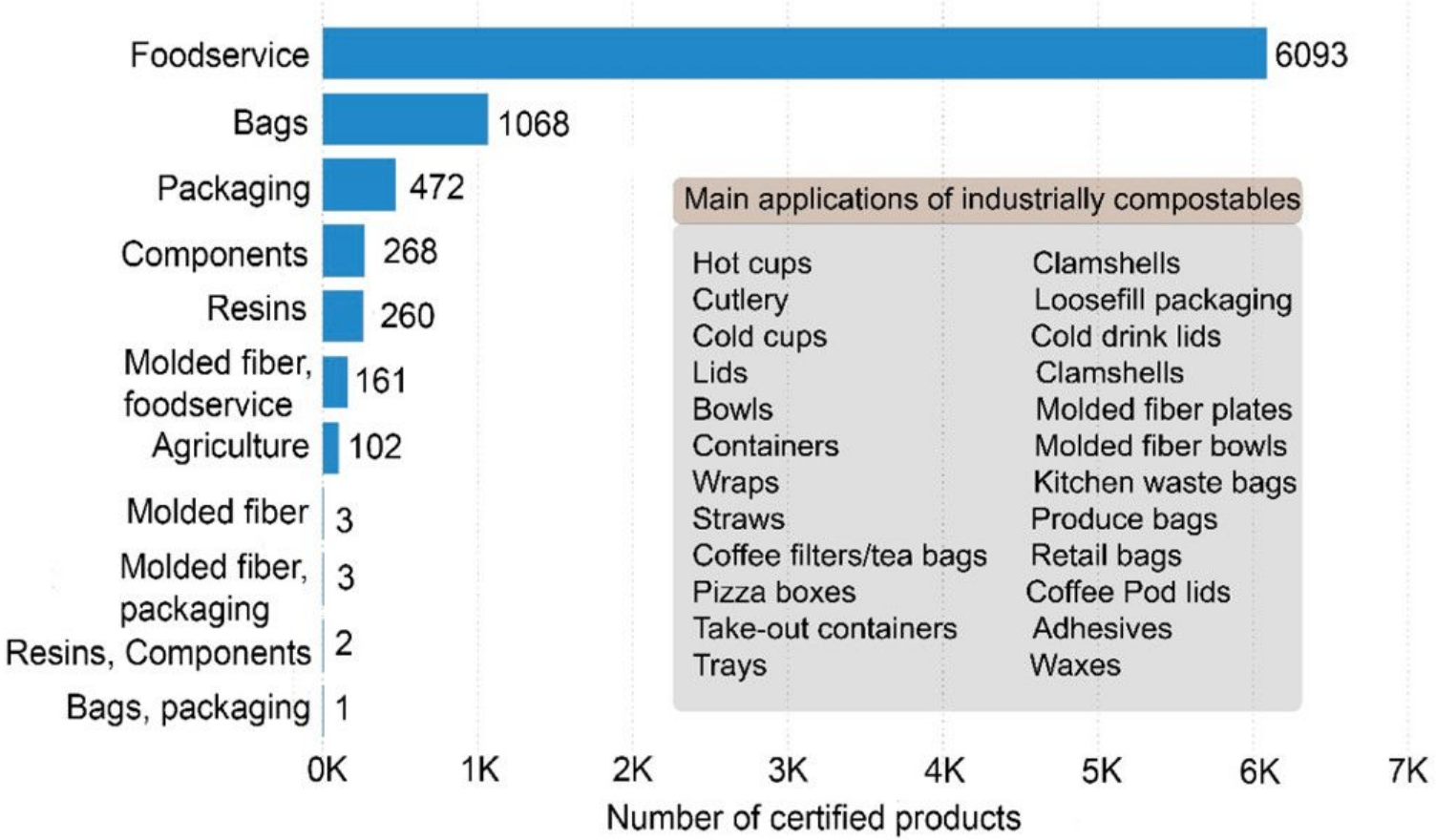




The *I. sakaiensis* bacterium discovered by Yoshida *et al.* can attach to PET. It produces two hydrolytic enzymes (PETase and MHETase) that catalyze the degradation of the PET fibers to form the starting monomers. The monomers are then catabolized by the bacterium as its sole carbon source.

SCIENCE 11 Mar 2016 Vol 351, Issue 6278 pp. 1154-1155 DOI: 10.1126/science.aaf28

Current landscape of application for industrial compostable products.



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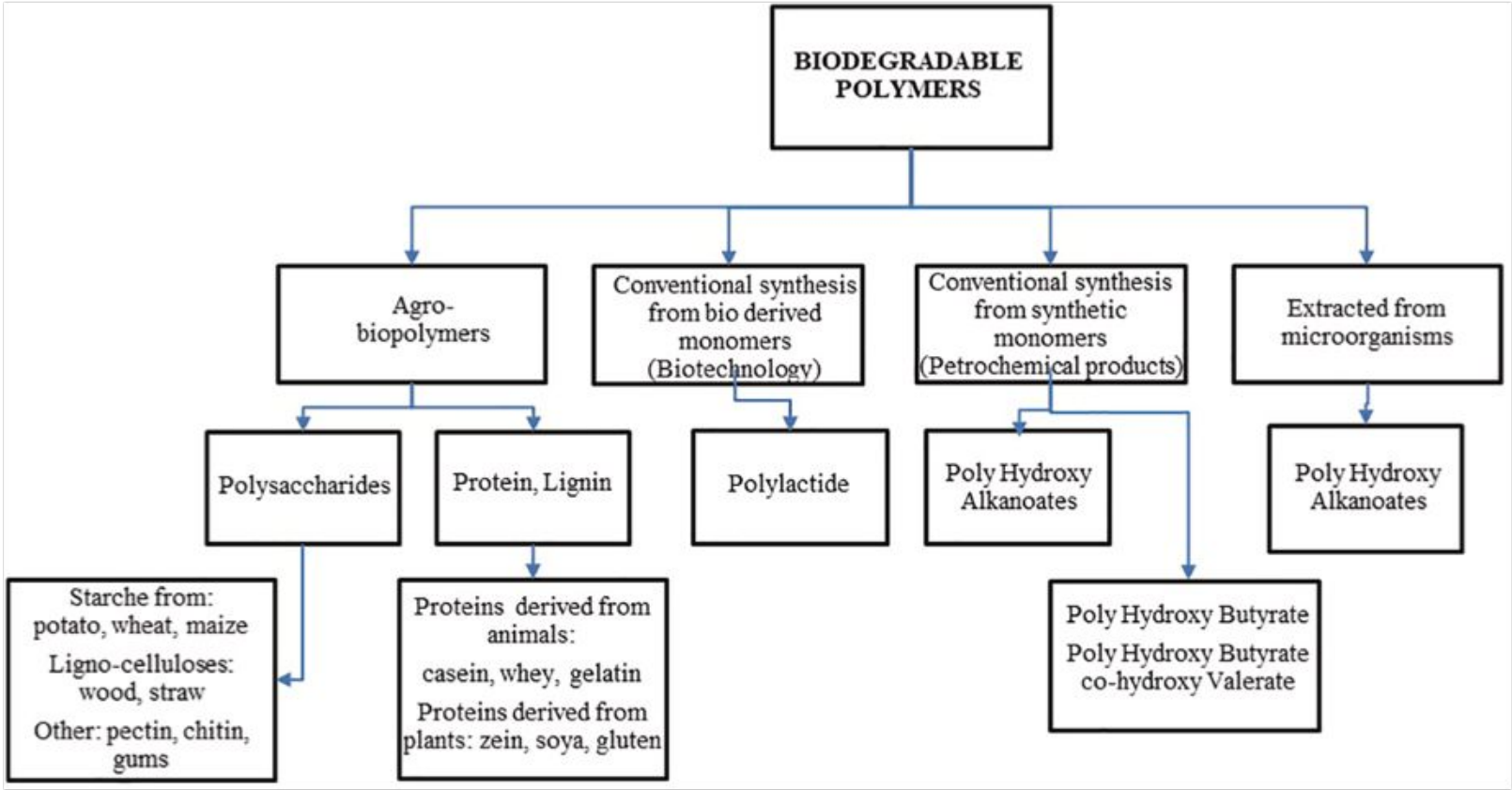
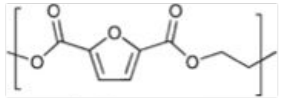
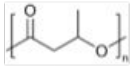
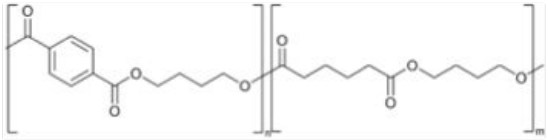
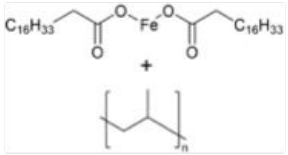
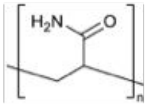


Fig. 3. Classification system of biodegradable polymers based on their origin.

https://doi.org/10.1016/j.biortech.2021.124739
Bioresource Technology 325 (2021) 124739

Definitions, examples, and chemical structures of bio-based, biodegradable, and oxo- and hydro-degradable plastics.

Table 1. Definitions, examples, and chemical structures of bio-based, biodegradable, and oxo- and hydro-degradable plastics.

Plastic	Definition	Example[a]	Chemical structure	Ref.
bio-based	a plastic made from renewable resources, namely biomass or waste	PEF		[31]
bio-degradable	a plastic that can be assimilated by bacteria and/or fungi to give environmentally friendly products	PHB (bio-based)		[30]
		PBAT (fossil-carbon-based)		[30]
oxo-degradable	a plastic whose degradability is induced by additives that initiate oxidation reactions	Oxo-PP		[20, 21]
hydro-degradable	a plastic whose degradability is induced by the polar groups susceptible to hydrolysis	PA		[24–27]

[a] PEF = polyethylene furanoate; PHB = poly-4-hydroxybutyrate; PBAT = polybutylene adipate terephthalate; Oxo-PP = oxo-degradable polypropylene; PA = polyacrylamide.

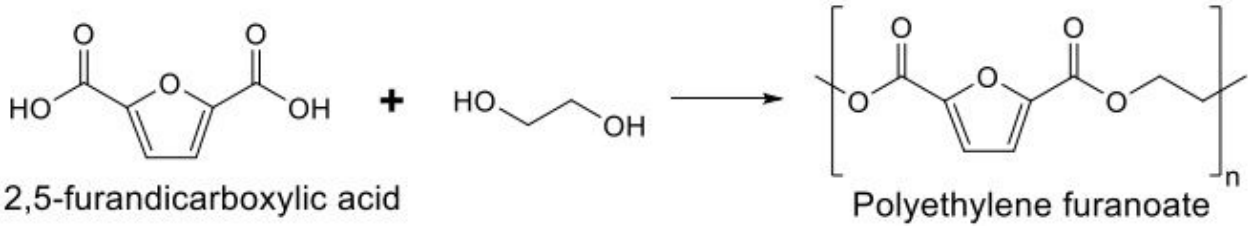
doi.org/10.1002/cssc.202002044 *ChemSusChem* 2021, *14*, 56 – 72

Biodegradable packaging for consumer products

Company	Sulapac	Shellworks	Teal	Nohbo	Notpla	Hero
Product	Cosmetic Jars	Cosmetic and Food Jars/Bottles	Cosmetic Jars	Single-dose water-soluble pods for personal care	100% edible and biodegradable packaging for food	Home Compostable Shipping Mailers for ecommerce stores
Materials	Ecovio from BASF	Vivomer is created by the microorganisms that are abundant in both marine and soil environments.	BioWorks PHA	Genomatica's natural Brontide™ butylene glycol.	Algae	Corn starch and PBAT
Breakdown	Industrial composting	Industrial composting in 12 months	Industrial composting	Instantly dissolves	Instantly dissolves	home-compost bin, 90-120 days
Industry	Cosmetics/Straws	Cosmetics/Food	Cosmetics	Personal Care	Food	Shipping Mailers
Funding/Headquarters	$20.9M/EU	$7.6M/EU	$0/USA	$3M/USA	£15.4M/EU	A$1.5M/AU

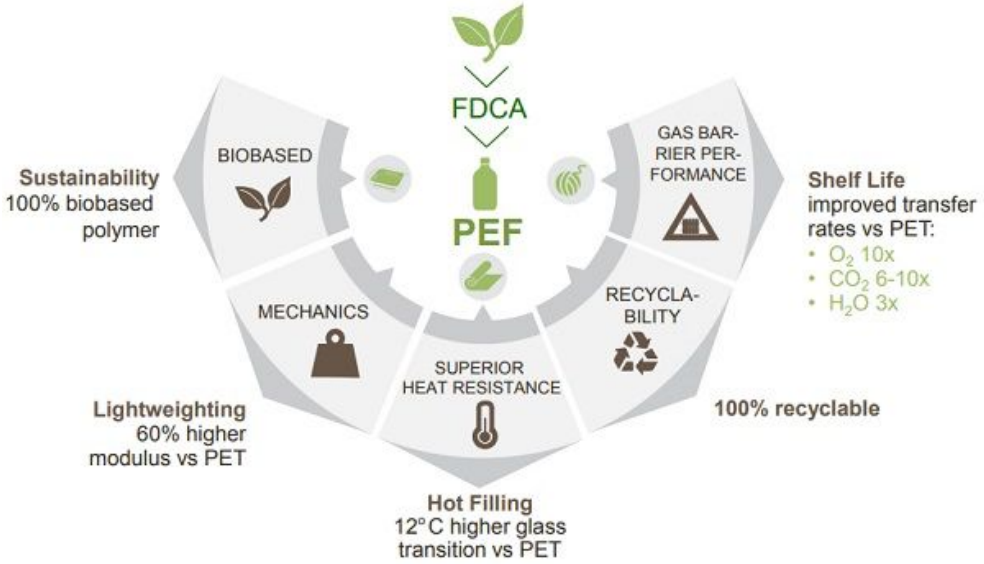
Coca-Cola says its plastic bottles will be biodegradable by 2023

PEF



2,5-furandicarboxylic acid

Polyethylene furanoate



Press Release

Bayer and yet2 Launch Innovation Challenge for Biodegradable Packaging Sachets/Tubes, Bayer Renews Commitment to Open Innovation

Bayer Consumer Health partners with yet2 and looks to external technologies to solve their latest sustainable packaging innovation challenge, helping accelerate towards their goal of 100% recyclable or renewable packaging by 2030.

Key requirements for potential submissions include:

- Sustainable packaging and material end-of-life
- Potential to scale to industrial packaging volumes
- Achieve the following Water Vapor and Oxygen Transmission Rates
- Solutions derived from bio-sourced or renewably sourced materials are preferred.

	Water Vapor Transmission Rate	**Oxygen Transmission Rate**
Sachet	**0.02 g/100in2/day** [@ 38°C, 90% RH]	**0.02 cc/100in2/day** [@ 22°C, 0% RH]
Flex Tube	**0.001 - 0.009 g/100in2/day** [@ 38°C, 90% RH]	**0.01 - 0.04 g/100in2/day** [@ 50°C, 50% RH]
Rigid Tube	**0.09 g/100in2/day** [@ 38°C, 90% RH]	**0.09 cc/100in2/day** [@ 22°C, 0% RH]

European Bioplastics recommends that compostable plastics should be promoted if the following criteria apply:

(1) Plastics are contaminated with food waste.

(2) Plastics whose expected fate is organic waste collection, and mechanical recycling is not possible.
(3) Plastics provide a potential to reduce nonbiodegradable plastic contamination of biowaste collection.
(4) Alternative reusable solutions cannot be redesigned.

Similarly, a series of drivers can be identified for promoting a case of soil biodegradable agricultural plastic products.

a) There is a short to medium shelf life in the field, on average from one to three seasons (3 years).
b) Plastic waste produced at the end of the use is contaminated with soil or other plant residues (e.g., nets for growing crops under greenhouses, geotextile applied in reforestation, or in landscaping).
c) Plastic waste is difficult to detach from plant residues or collect (e.g., pheromone dispensers, clips, twines).118 In this case the organic residue is contaminated with plastic.

In the third application, the water biodegradable plastics offer certain benefits where the large quantities of materials migrate into nature as a part of their normal usage. The cosmetic industry, for example, has a regulatory and environmental need to develop lubricants and microbeads that are biodegradable in water.119,120

https://doi.org/10.1021/acssuschemeng.1c00801
ACS Sustainable Chem. Eng. 2021, 9, 6170−6187

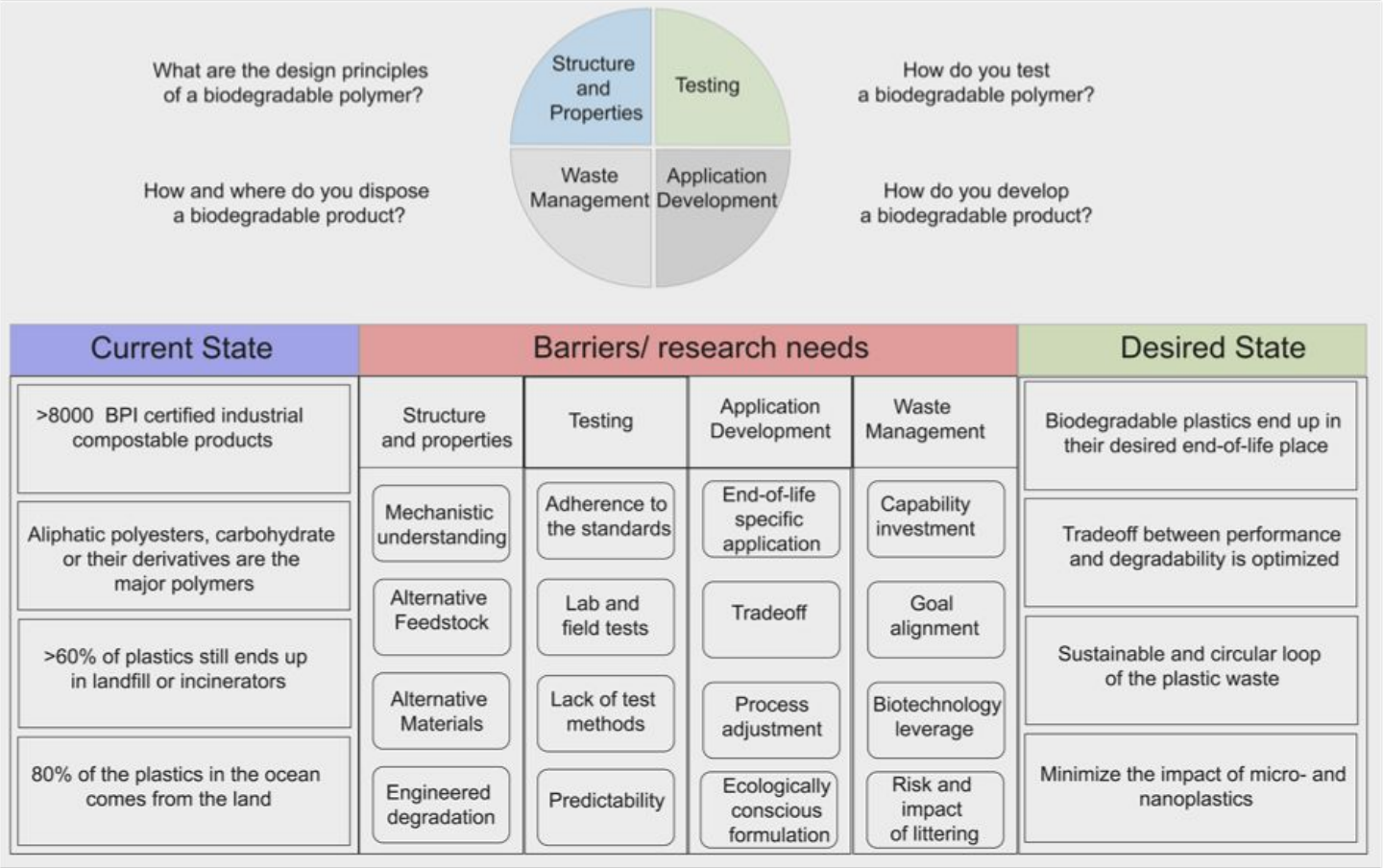


Figure 4. Roadmap to biodegradable plastics.

https://doi.org/10.1021/acssuschemeng.1c00801
ACS Sustainable Chem. Eng. 2021, 9, 6170−6187

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Cover photo: https://www.chemistryworld.com/ Waste not, want rot. **AISLING IRWIN** 25 FEBRUARY 2019