Plastic degrading microorganisms: Opening an avenue to a sustainable world?

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Opening an avenue to a sustainable world?

Plastic Age

- **Plastics Make it Possible: A remarkable material**
- **Propelled rapid recent human progress & revolutionised industries**

car safety, firefighter gear, sunglasses, insulation, sports performance, space suits, medicine, electronics & IT…..

- **High mechanical performance, safe, lightweight, durable yet maliable**
- **Achieved by intense scientific and engineering developments over recent decades**
- **Ideal packaging, convenient for consumers**

-Keeps food fresh & lets shoppers view items

-Secures fragile items.

- **Safe shatter & tamper proof**
- **Sports Performance**

-world's lightest soccer boots

- **Plastics impact every part of modern cars, from performance to aesthetics**

make up 10% of vehicle's total weight, yet over 50 % of the volume.

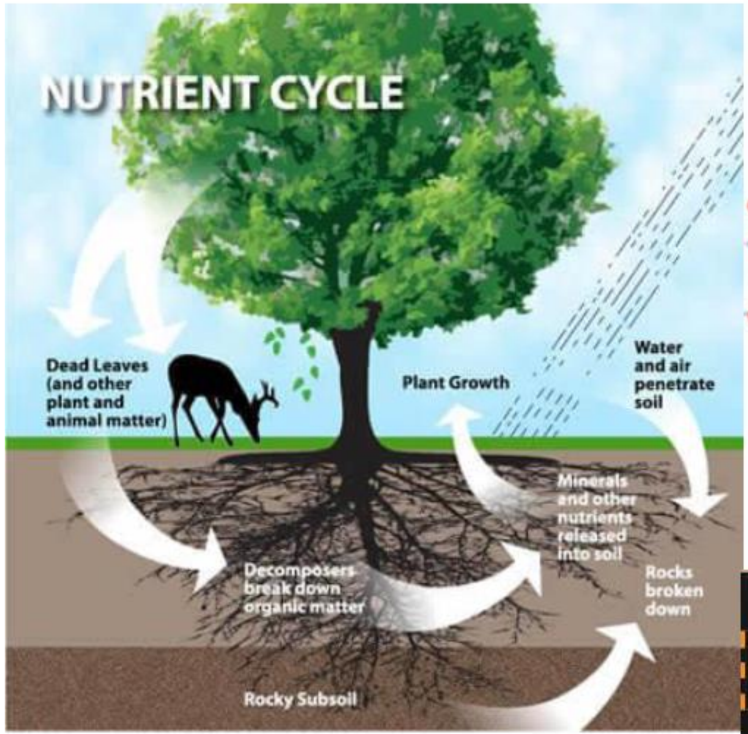
Plastics: An Unfinished Technology

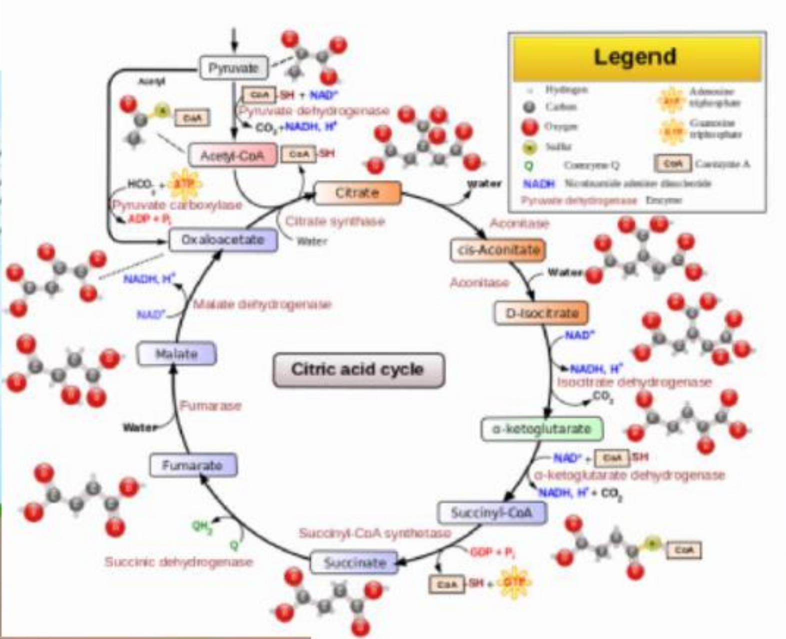
Petroleum –based plastics take 100s of years to degrade in soil & seawater ensuring a long-lasting blight on:
-our oceans,
-countryside
-& newly recognised our food system

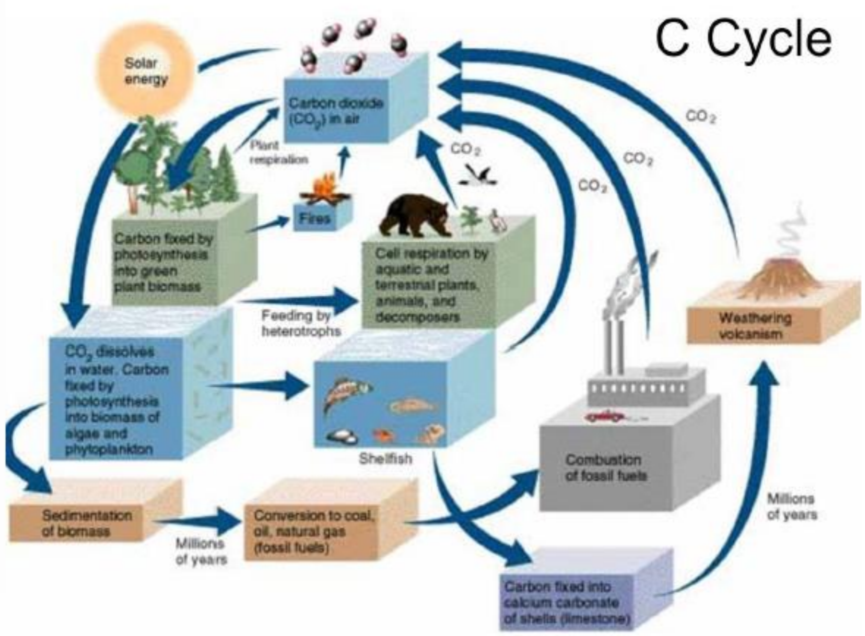
www.bioicep.eu

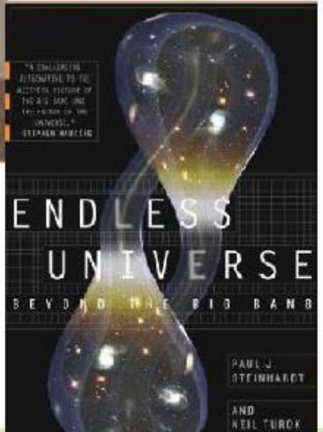
Plastics: Completing the Life Cycle

- **Nature operates a myriad of elegant & efficient regenerative cycles**









The evolution of the universe is cyclic with big bangs occurring once every trillion or so,

Paul J. Steinhardt and Neil Turok,

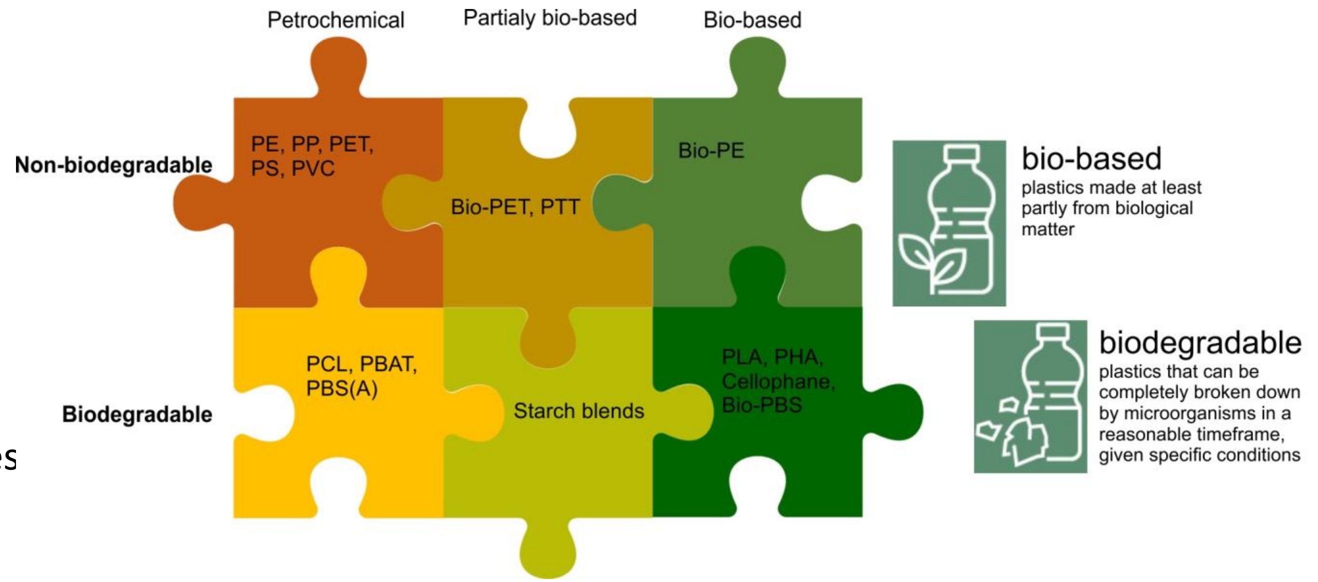
Princeton & Cambridge Universities

Challenges to completing the life cycle for plastics

- **Recycling technologies and infrastructures**: Largely fail and are unlikely to hold the answer to sustainable management or effective revalorization of post use and end of life plastics.
  - Economically, conventional recycling only makes sense when clean material is available in high quantities with advanced systems for mixed stream sorting.
  - Collection logistics, management of intrinsic human behavior, and diminished mechanical performance on reprocessing, dictates that plastics can not be perpetually conventionally recycled.

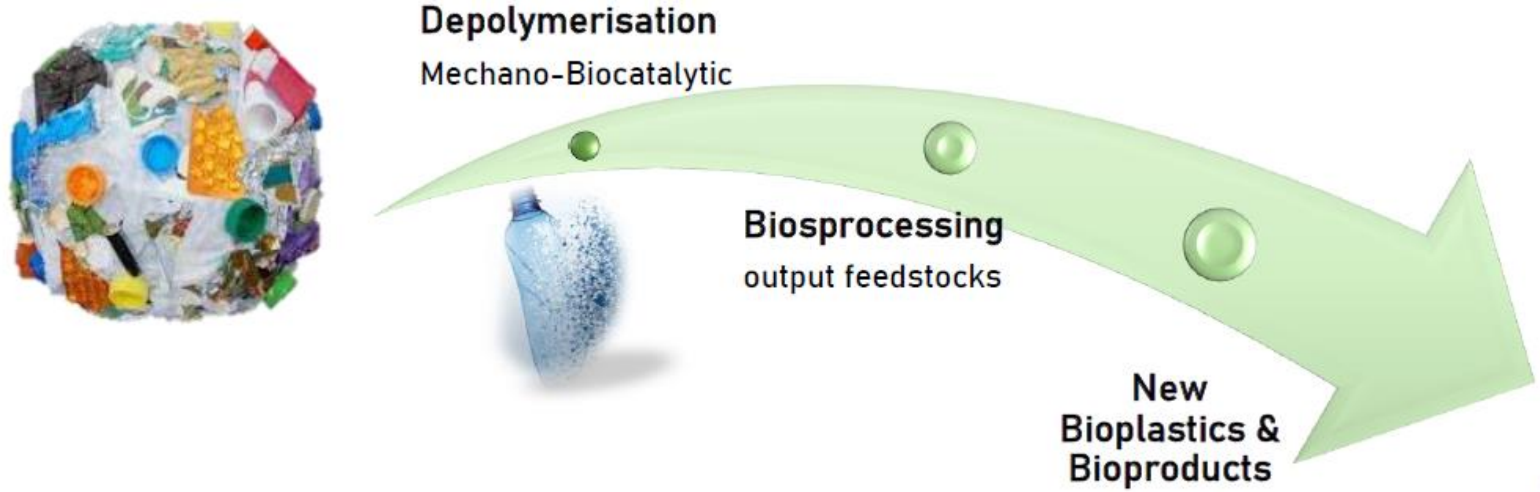
- **Recalcitrant nature of plastics:** Strongly bio-inert and largely incompatible with bioprocessing
  - Smooth surface topographies, extensive hydrophobic chains, lack of bioaccessible organic chemical groups

- **Bioplastics:** Not achieved wide acceptability by industry with current market penetration levels of just 2%
  - Incompatibility with existing sorting infrastructures and high temperature mechanical recycling
  - Raised costs are limiting factors.
  - Technical shortcomings, such as brittleness, lower gas barrier functions and processing performances
  - Mixed options available

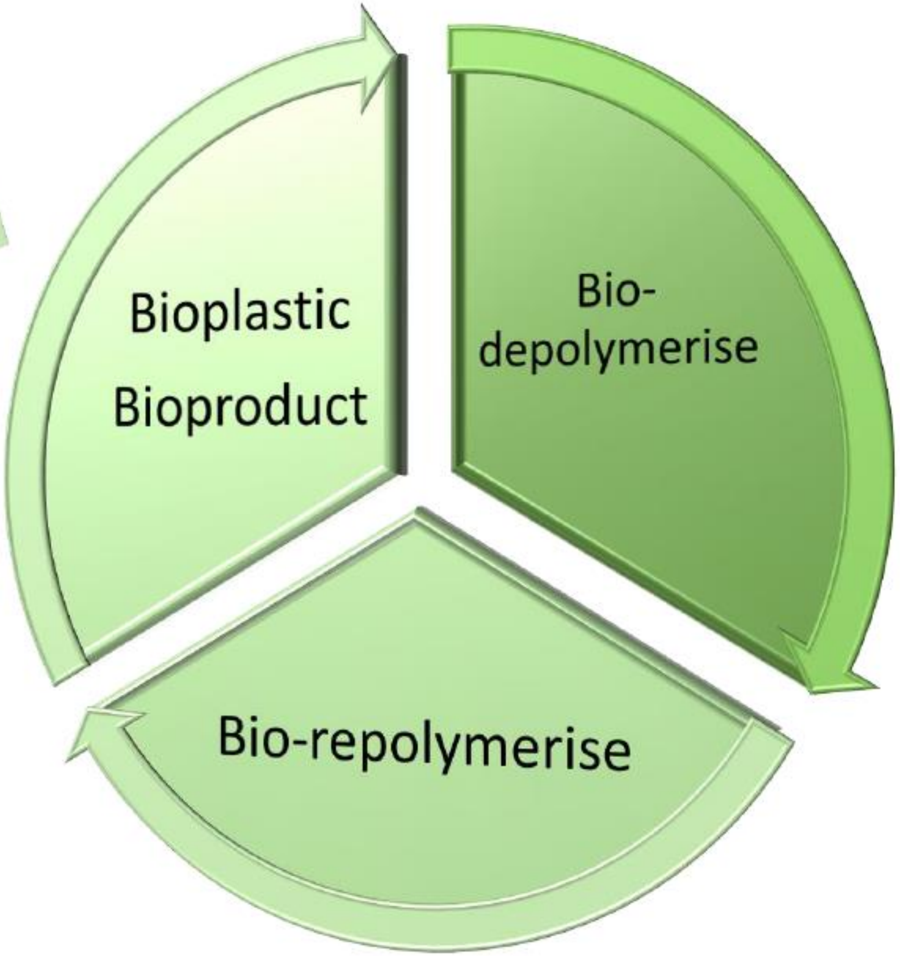


- **Bio-recycling & regenerative technologies for current plastic materials?**

Overarching BioICEP Approaches

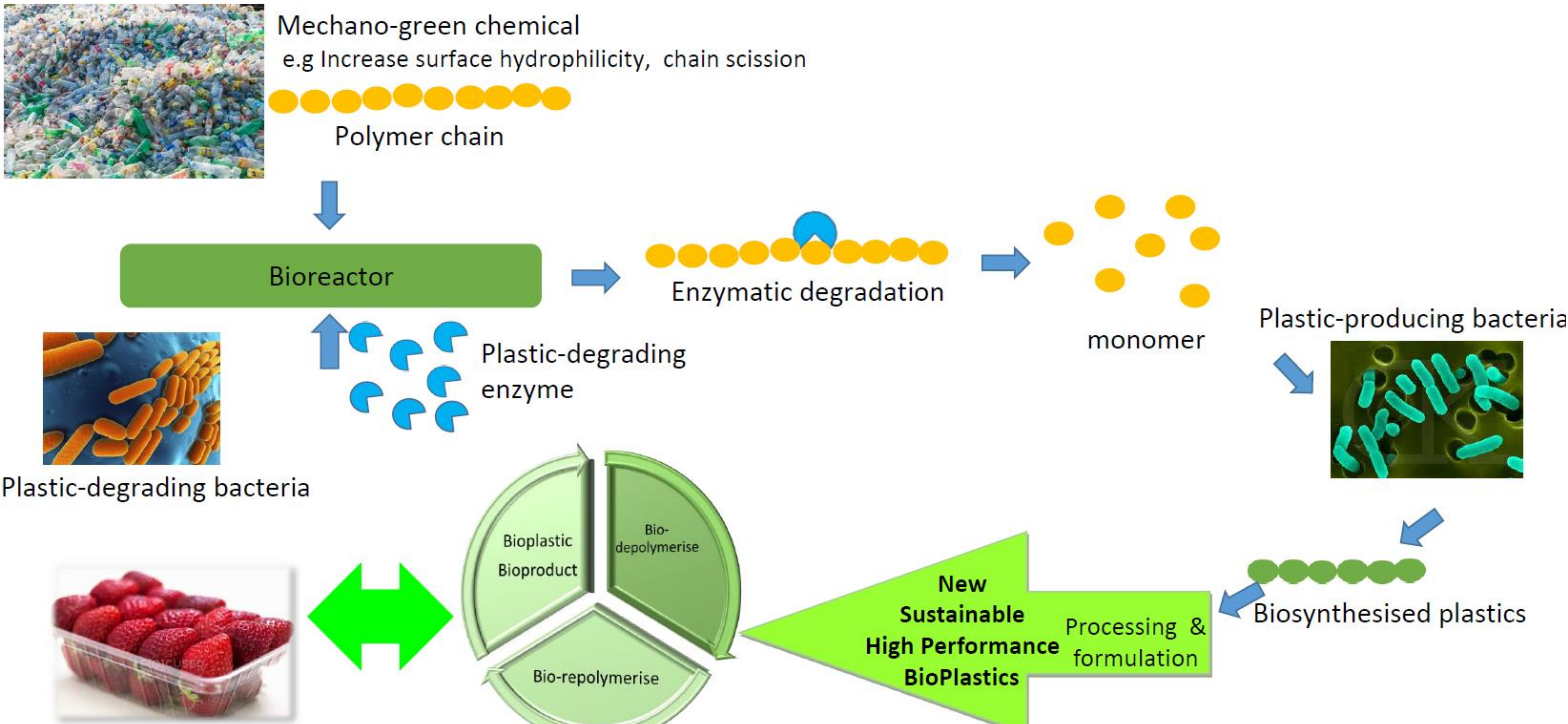


Biocyclable Equivalent BioPlastics

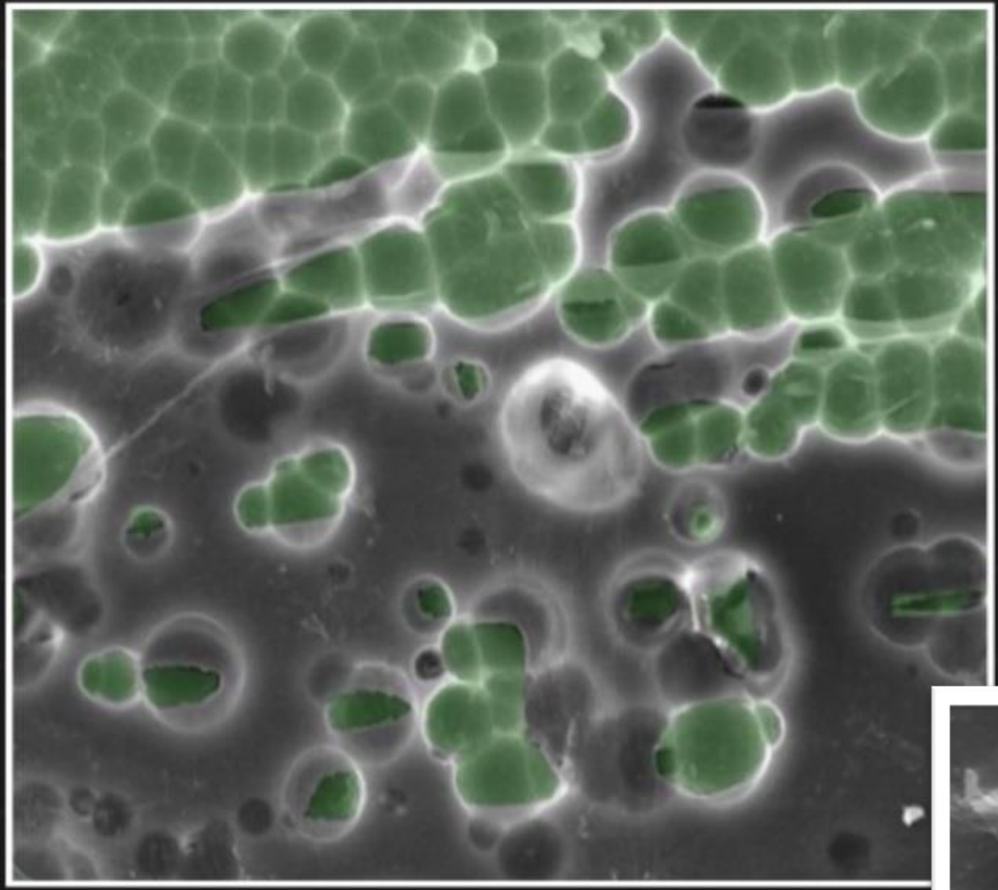


Accelerate degradation of mixed waste plastic
& valorise as biopolymers and bioproducts
as sustainable replacement plastics – **Plastics 2.0**.

Syphoning Recalcitrant Plastic into Bio Cyclable Plastics



Bio-depolymerization

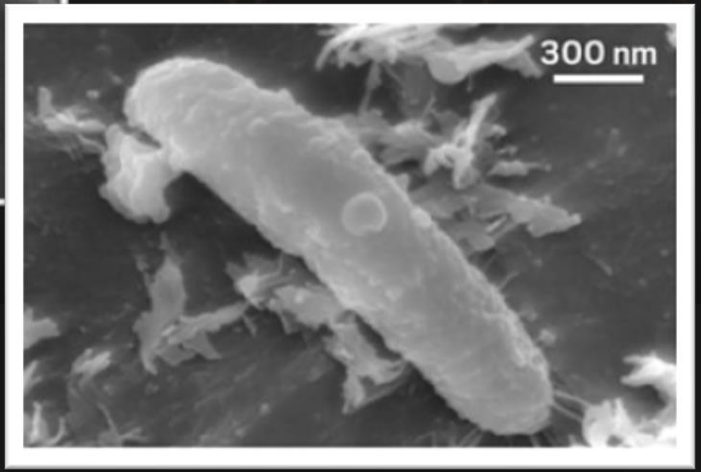


NEWLY DISCOVERED MICROBE

- SHRINK TIME PLASTIC TAKES TO DEGRADE
- FROM HUNDREDS OF YEARS ... TO A FEW DAYS

IDEONELLA SAKAIENSIS

(2016)



Bacteria, fungi, and enzymes associated with polyethylene petrochemical plastic biodegradation

Enzyme	Isolated source	Tested PET	Crystallinity, %	Reaction temperature, °C	Incubation time, d	Weight loss, %
TfH	*Thermobifida fusca*	PET bottle and pellets	9	55	21	54.2
HiC; PmC; PsC	*Humicola insolens; Pseudomonas mendocina; Fusarium solani*	Low-crystallinity PET film	7	70	6	97%
LC-cutinase	Compost metagenomic library	Low-crystallinity PET film	8.4	50	7	50
Cut190	*Saccharomonospora viridis*	Low-crystallinity PET film	8.4	63	3	27
*Is*PETase	*Ideonella sakaiensis*	Low-crystallinity PET film	1.9	30	0.75	–
*Is*PETase	*Ideonella sakaiensis*	Low-crystallinity PET film	–	30	1	1
TfCut2	*Thermobifida fusca*	Low-crystallinity PET chip	7	70	5	97

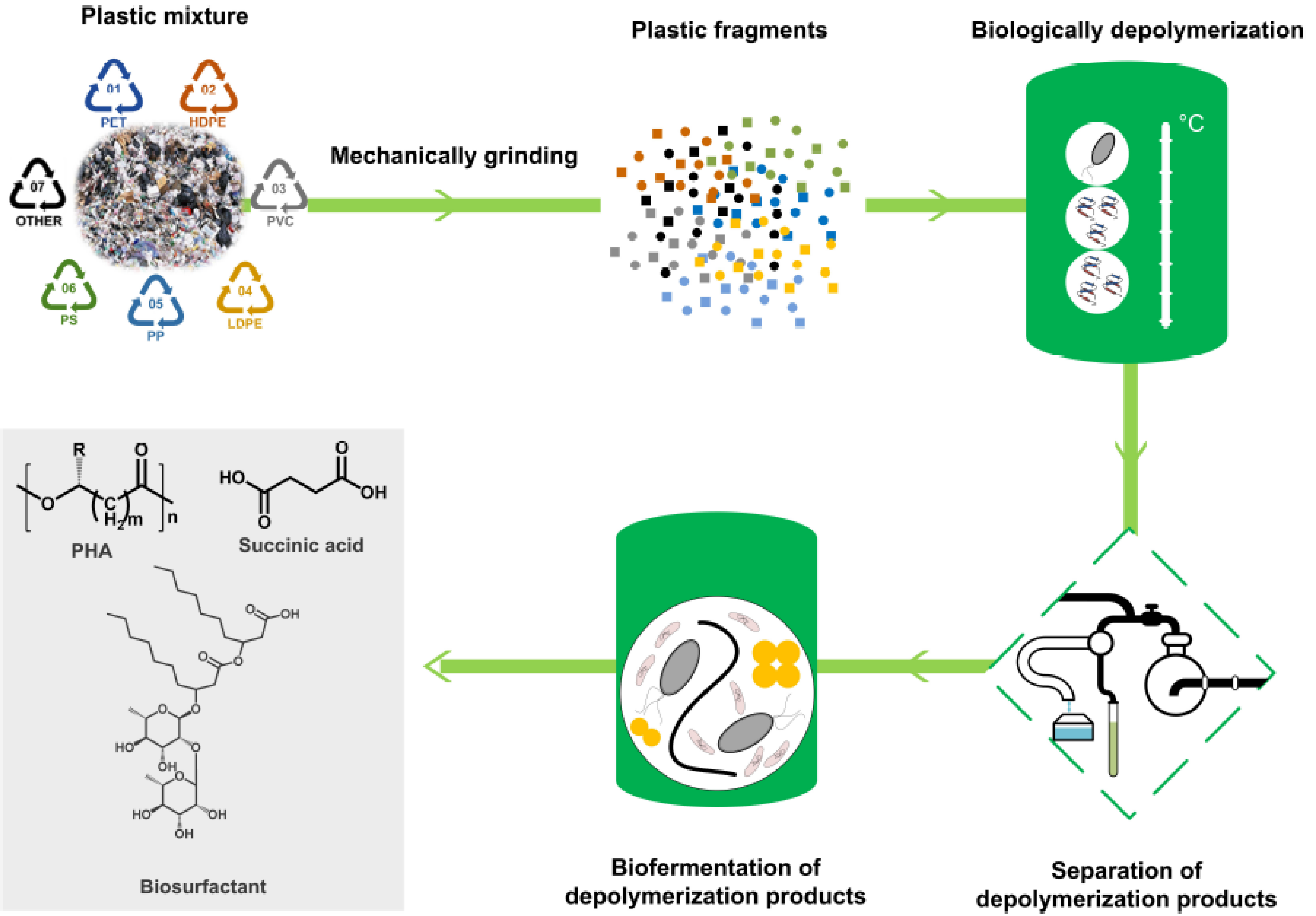
4
LDPE

Strain/Enzyme	Isolated source	Tested PE	Incubation time, d	Weight loss, %	Molecular weight	Degradation products
Rhodococcus ruber C208	Soil of disposal site	LDPE film	30	4	–	–
Bacillus sphericus Alt; *Bacillus cereus* BF20	Marine water	LDPE film	180	2.5–10	–	–
Arthrobacter sp. GMB5; *Pseudomonas* sp. GMB7	Plastic waste dumpsites	HDPE film	30	12–15	–	–
Pseudomonas sp. E4	Soil	LMWPE	80	–	–	–
Pseudomonas sp. AKS2	Waste dumping soil	LDPE film	45	5	–	–
Bacillus subtilis H1584	Marine water	LDPE film	30	1.75	–	–
Enterobacter asburiae YT1; *Bacillus* sp. YP1	Gut of waxworm	LDPE film	60	6–11	Decreased	Detected
Serratia marcescens	Ground soil	LLDPE film	70	36	–	–
Achromobacter xylosoxidans	Soil	HDPE film	150	9.38	–	–
Zalerion maritimum	Marine environment	PE pellets	28	–	–	–
Phormidium lucidum; *Oscillatoria subbrevis*	Domestic sewage water	LDPE film	42	–	–	–
Alcanivorax borkumensis	Mediterranean Sea	LDPE film	7	3.5	–	–
manganese peroxidase	*Phanerochaete chrysosporium*	PE film	12	–	Decreased	–
soybean peroxidase	Soybean	HDPE film	2 h	–	–	–
laccase	*Rhodococcus ruber* C208	LDPE film	30	2.5	Decreased	–
alkB gene	*Pseudomonas* sp. E4	LMWPE sheet	80	19.3	–	–
alkB1, *alkB2* gene	*Pseudomonas aeruginosa* E7	LMWPE film	50	19.6–27.6	–	–

Strain/Enzyme	Isolated source	Tested PS	Incubation time, d	Weight loss, %	Molecular weight	Degradation products
Xanthomonas sp.; *Sphingobacterium* sp.; *Bacillus* sp. STR-YO	Field soil	PS film	8	40–56	–	–
Rhodococcus ruber C208	Soil of disposal site	PS film	56	0.8	–	–
Microbacterium sp. NA23; *Paenibacillus urinalis* NA26; *Bacillus* sp. NB6; *Pseudomonas aeruginosa* NB26	Soil buried expanded PS film	PS film	56	–	–	Detected
Rhizopus oryzae NA1; *Aspergillus terreus* NA2; *Phanerochaete chrysosporium* NA3	Soil buried expanded PS film	PS film	56	–	Increased	Detected
Exiguobacterium sp. YT2	Mealworm's gut	PS film	60	7.5%	Decreased	Detected
hydroquinone peroxidase	*Azotobacter beijerinckii* HM121	PS film	20 min	–	Decreased	Detected

Strain/Enzyme	Isolated source	Tested PP	Incubation time, d	Weight loss, %	Molecular weight	Degradation products
Pseudomonas stutzeri; Bacillus subtilis; Bacillus flexus	Plastic-dumping site	PP film	365	–	–	Detected
Phanerochaete chrysosporium; *Engyodontium album*	Plastic-dumping site	PP film	365	4–5	–	Detected
Stenotrophomonas panacihumi	Soil of waste storage yard	PP film	90	–	Increased	–
Aneurinibacillus aneurinilyticus; *Brevibacillus agri*; *Brevibacillus* sp.; *Brevibacillus brevis*	Landfills and sewage	PP film and pellets	140	22.8–27.0	–	Detected
Bacillus sp. strain 27; *Rhodococcus* sp. strain 36	Mangrove environments	PP microplastic	40	4–6.4	–	–

Strain/Enzyme	Isolated source	Tested PVC	Incubation time, d	Weight loss,%	Molecular weight	Degradation products
Alternaria sp. TOF-46	Japanese bathrooms	Plasticized PVC rim	180	–	–	–
Poliporus versicolor; Pleurotus sajor caju	Lignocellulosic waste	PVC film	30	–	–	Detected
Aureobasidium pullulans	Leaf/wood surfaces	Plasticized PVC	7	–	–	–
Aspergillus niger	PVC wires	Plasticized PVC film	365	–	–	–
Aureobasidium pullulans	Atmosphere	Plasticized PVC film	42	3.7	–	–
Penicillium janthinellum	PVC buried in soil	Plasticized PVC sheet	300	–	–	–
Mycobacterium sp. NK0301	Garden soil	Plasticized PVC film	3	–	–	Detected
Chryseomicrobium imtechense; *Lysinibacillus fusiformis*; *Acinetobacter calcoaceticus*; *Stenotrophomonas pavanii*	Landfill leachate	Plasticized PVC curtain	34	–	–	–
Phanerochaete chrysosporium; *Lentinus tigrinus*; *Aspergillus niger*; *Aspergillus sydowii*	PVC film buried in soil	PVC film	300	–	Decreased	Detected
Acanthopleurobacter pedis; *Bacillus cereus*; *Pseudomonas otitidis*; *Bacillus aerius*;	Plastic disposal sites	PVC film	90	–	Decreased	Detected
Bacillus sp. AIIW2	Marine	Un-plasticized PVC film	90	0.26	–	Detected
Phanerocheate chrysosporium	Plastic disposal site	PVC film	28	31	–	Detected
Pseudomonas citronellolis	Soil	Plasticized PVC film	45	13	Decreased	–


Plastic mixture
01
PET
02
HDPE
03
PVC
04
LDPE
05
PP
06
PS
07
OTHER
Mechanically grinding
Plastic fragments
Biologically depolymerization
°C
Separation of
depolymerization products
Biofermentation of
depolymerization products
PHA
Succinic acid
Biosurfactant

(2020 – 2023)

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Thanks!

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