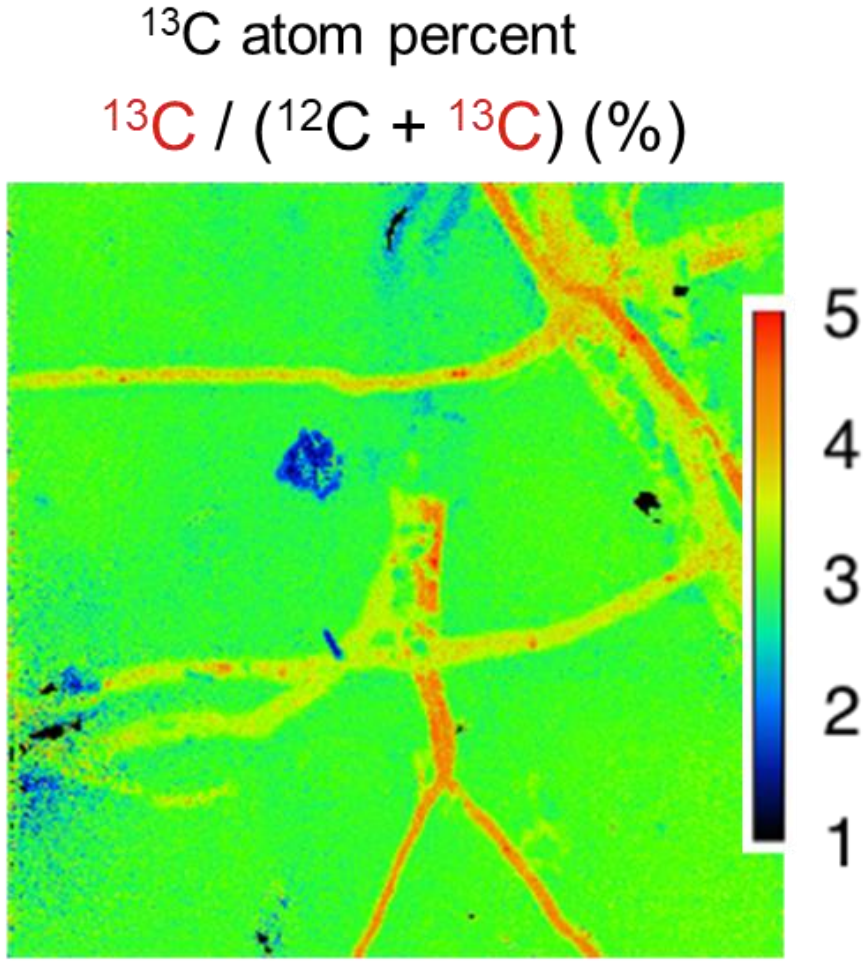
“Biodegradable and biobased materials: Contributions to a circular economy”

Prof. Dr. Andreas Künkel

Vice President, BASF SE

Nordic Bioplastic Conference

Copenhagen, Denmark, 13th of April 2023



Biodegradation

The circular economy vision with use of biodegradable and biobased materials – how to close the nutrient loops

Case study today

Mulch Films

“Biosackerl”

Case study today

Compostable Packaging

➔ Biodegradable polymers as enabler for organic waste recycling and closing the loop – case study “Biosackerl” in Austria

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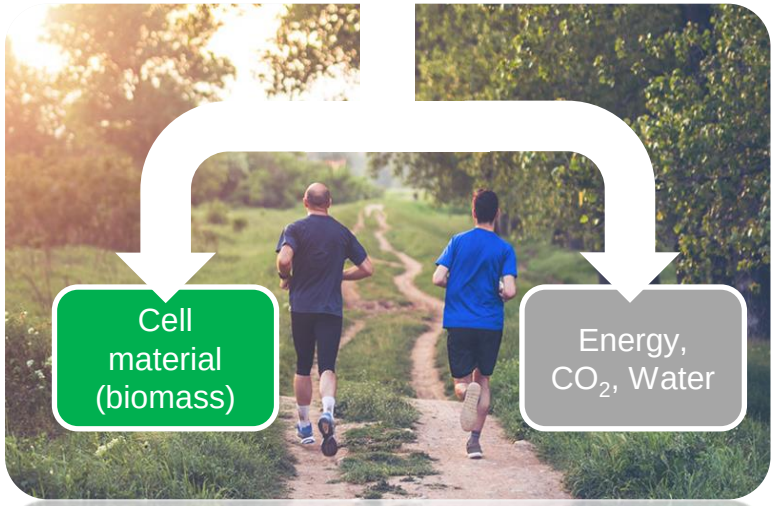
Biodegradability understanding

What is biodegradability?

Humans

Food biopolymers

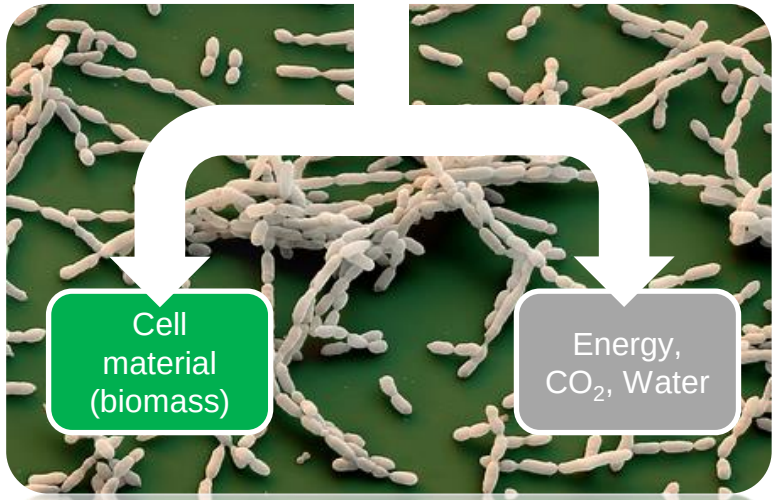
(e.g. starch, proteins)



Microorganism

„Food“ biopolymers

(e.g. starch, proteins, synth. biodegr. polymers)



Biodegradation = microorganisms metabolize the polymeric material completely to energy, CO_2, water & biomass (aerobic process)

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Biodegradation in soil

Biodegradable mulch film ecovio® M2351 mulch

End of life research

- Generate a fundamental understanding of the biodegradation process and fate of material
- Correlation of laboratory and field

ETH zürich

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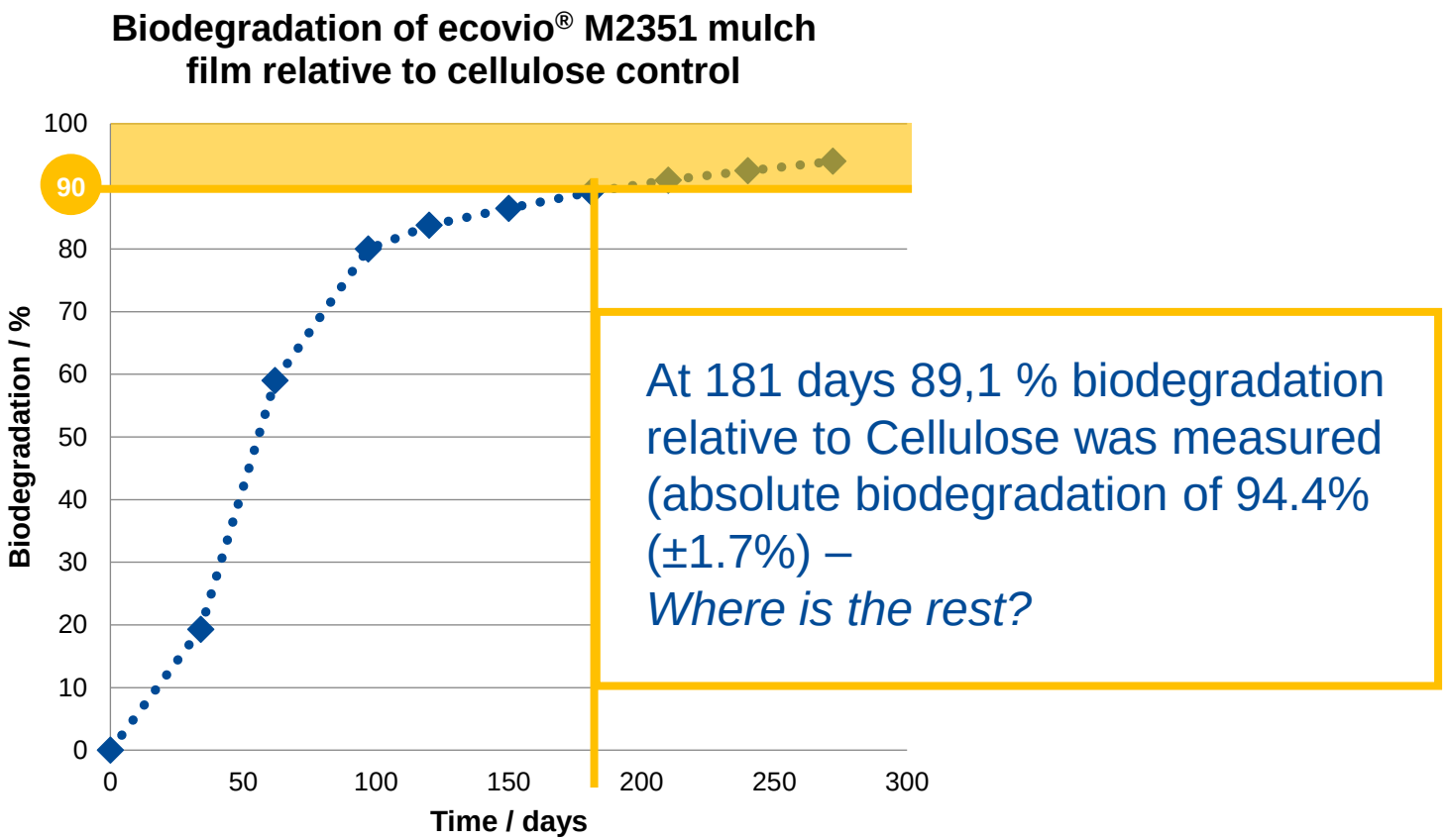
Biodegradation in soil

ecovio® M2351 mulch – Biodegradation in soil according to ISO 17556



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SOIL — OK bio-degradable — VINÇOTTE

CERTIFICATE FOR AWARDING AND USE OF THE "OK BIODEGRADABLE SOIL" CONFORMITY MARK

No. O 14-1416-A

Issued by AIB-VINÇOTTE International

For the product(s) described hereafter :

Product Domain :	Products Biodegradable in SOIL
Product Group :	Raw materials
Product Family :	Bio material
Product Type :	In form of Resin or Granulates
Trade mark :	Ecovio M2351
Product description / Particularities :	Colour: natural white

Conformity examination applied for by :
BASF SE
G-PMPB - F206
67056 Ludwigshafen
Germany

Criteria for certification :
- AVI Test Program with ref OK 10 edition C "Bio-products – degradation in soil"

Validity of the certificate : From 25 September 2014 till 25 September 2019

Conclusions of the examination :
The products comply with the above mentioned certification criteria, as confirmed by the test report of AVI no 09 / 60159490 / 409344p.

Applicable certification system :
Type examination followed by supervision through verification tests on samples from the distributor's stocks or of the market.
The conformity of the product is guaranteed by the procedures for awarding and use of the 'OK biodegradable SOIL' conformity mark. This only applies for specimen bearing the 'OK biodegradable SOIL' mark.

This certificate is issued in English, German, Italian, French and Spanish.

Brussels, 25 September 2014

For the Certification Committee

P. MICHIELS
Contract Manager

Ph. DEWOLFS
President of the Committee

Annex : /

08-CERTOKS-c

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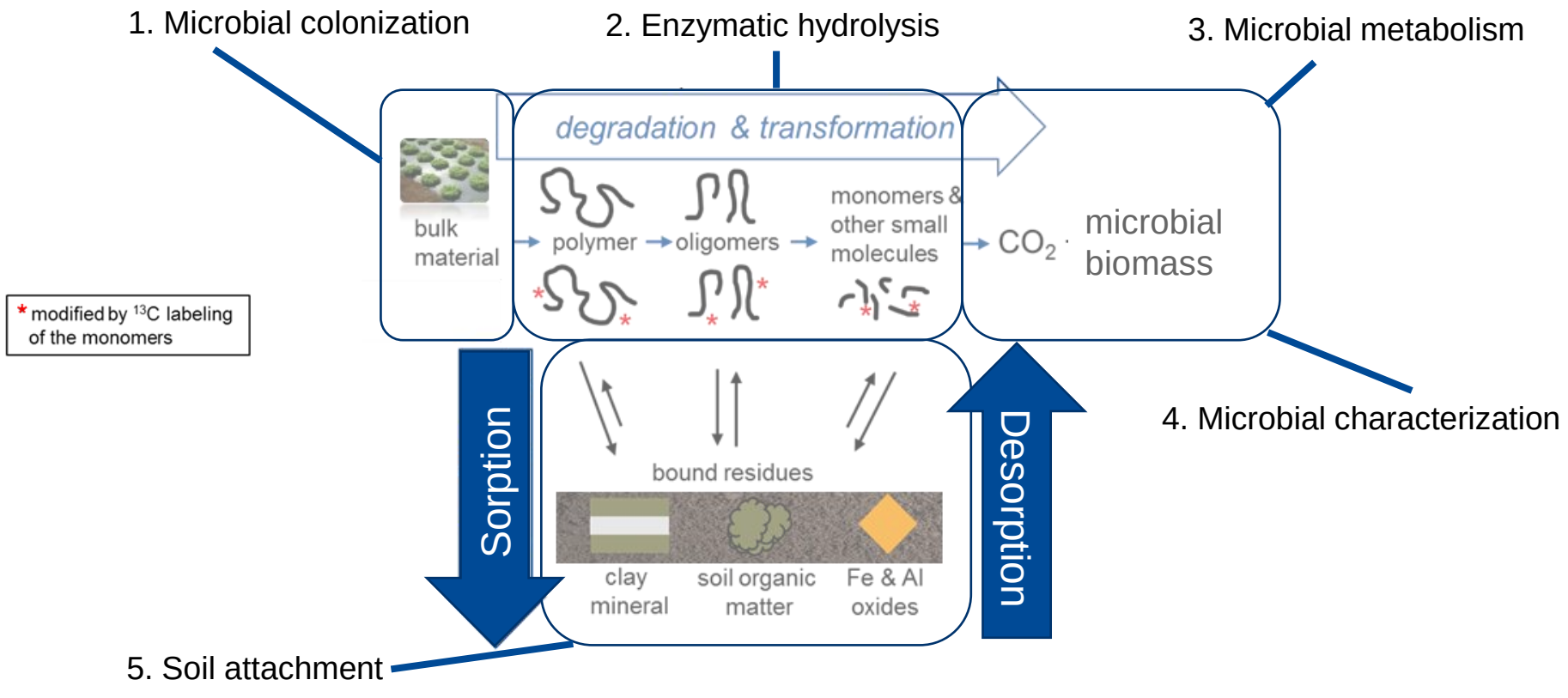
Biodegradation in soil

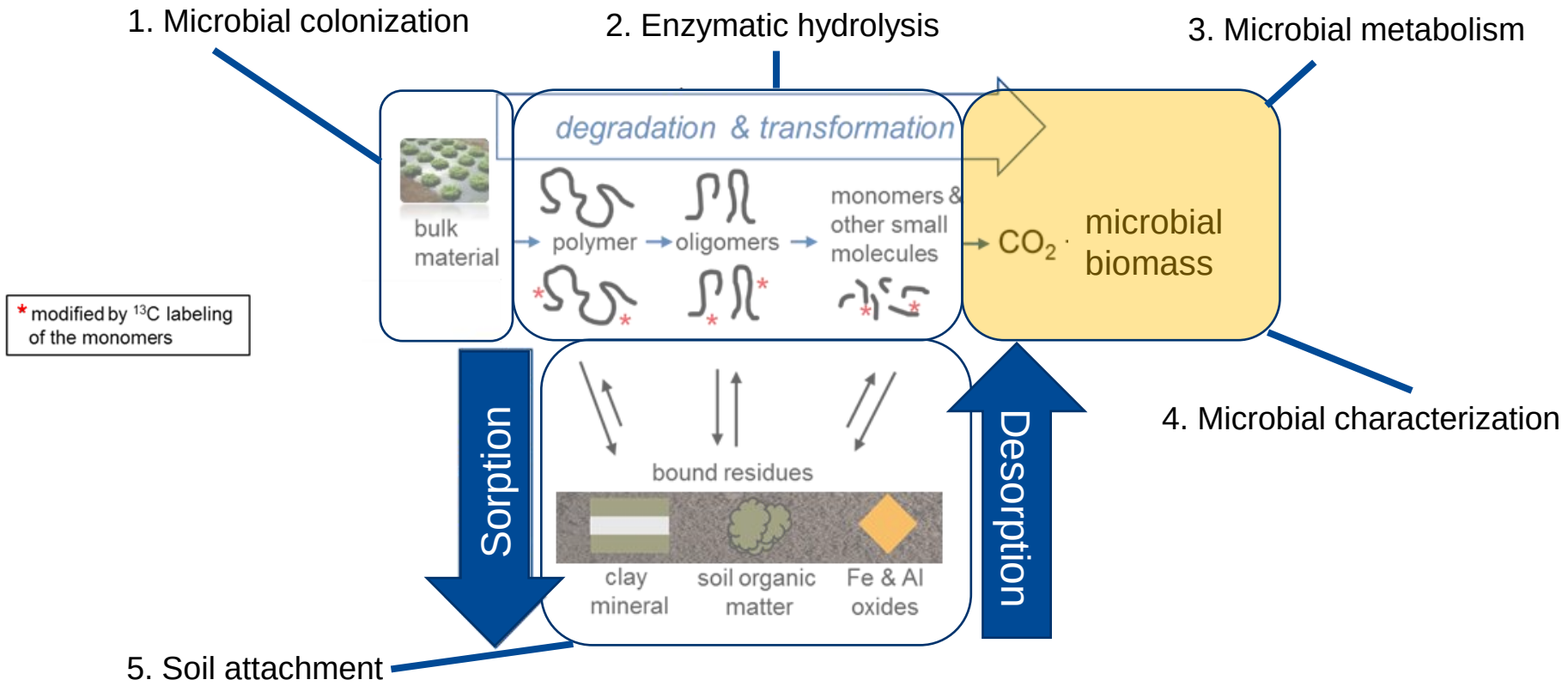
Decisive methods for understanding biodegradation in soil of ecovio® mulch film



Where does the polymer carbon end up?

Biodegradation in soil

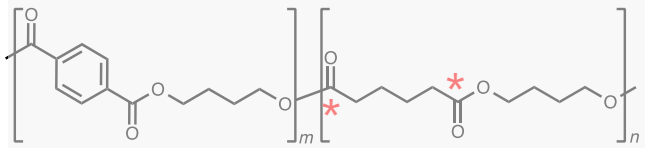
Decisive methods for understanding biodegradation in soil of ecovio® mulch film



Where does the polymer carbon end up?

Biodegradation in soil

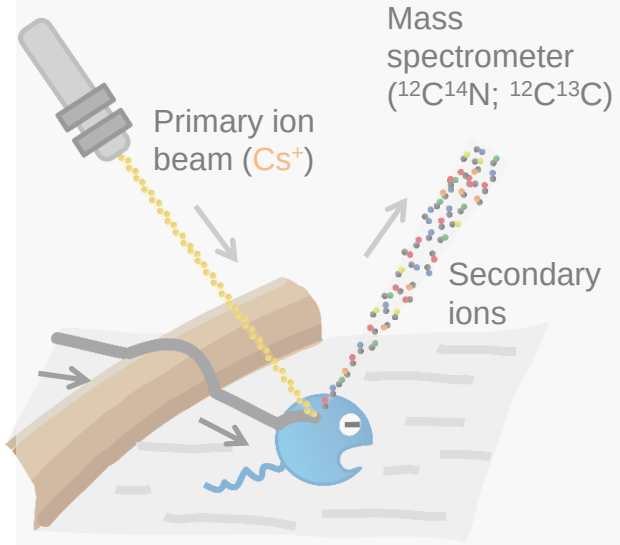
Conversion into microbial biomass

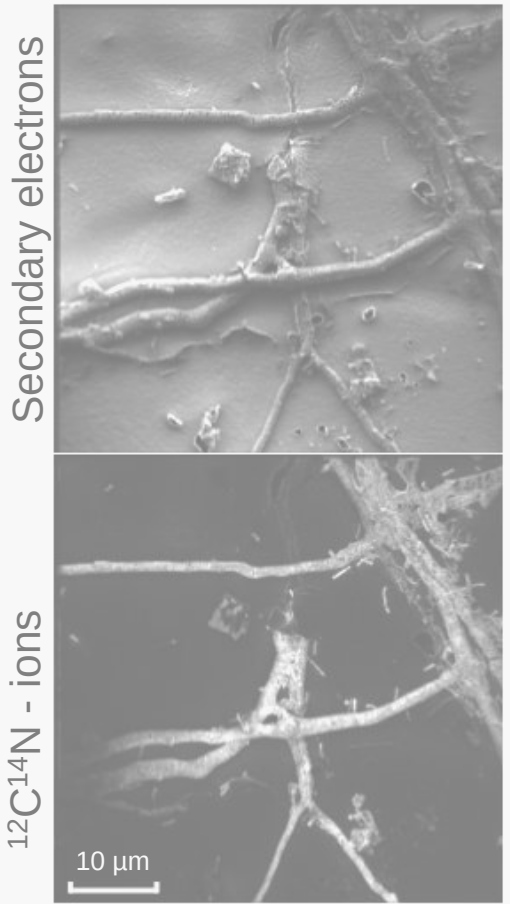


poly(butylene adipate-co-terephthalate)
PBAT: labeled in adipate

Zumstein et al.,Science Advances 2018;**4**:eaas9024

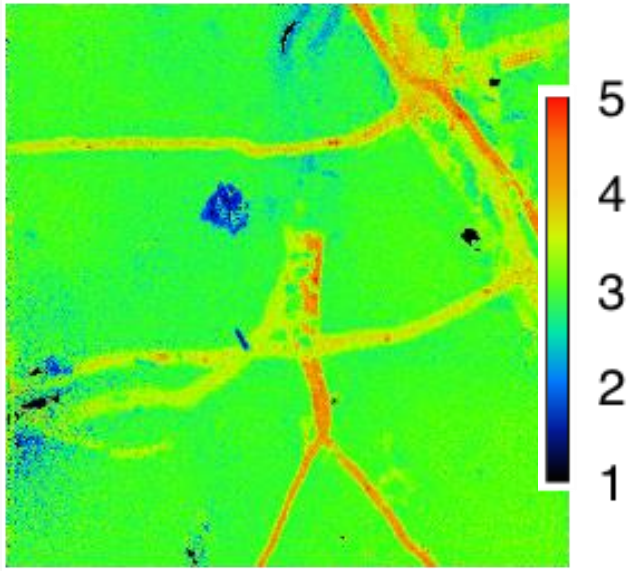
Nanoscale secondary ion mass spectrometry (NanoSIMS)





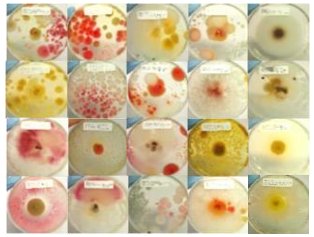
^{13}C atom percent

^{13}C / (^{12}C + ^{13}C) (%)

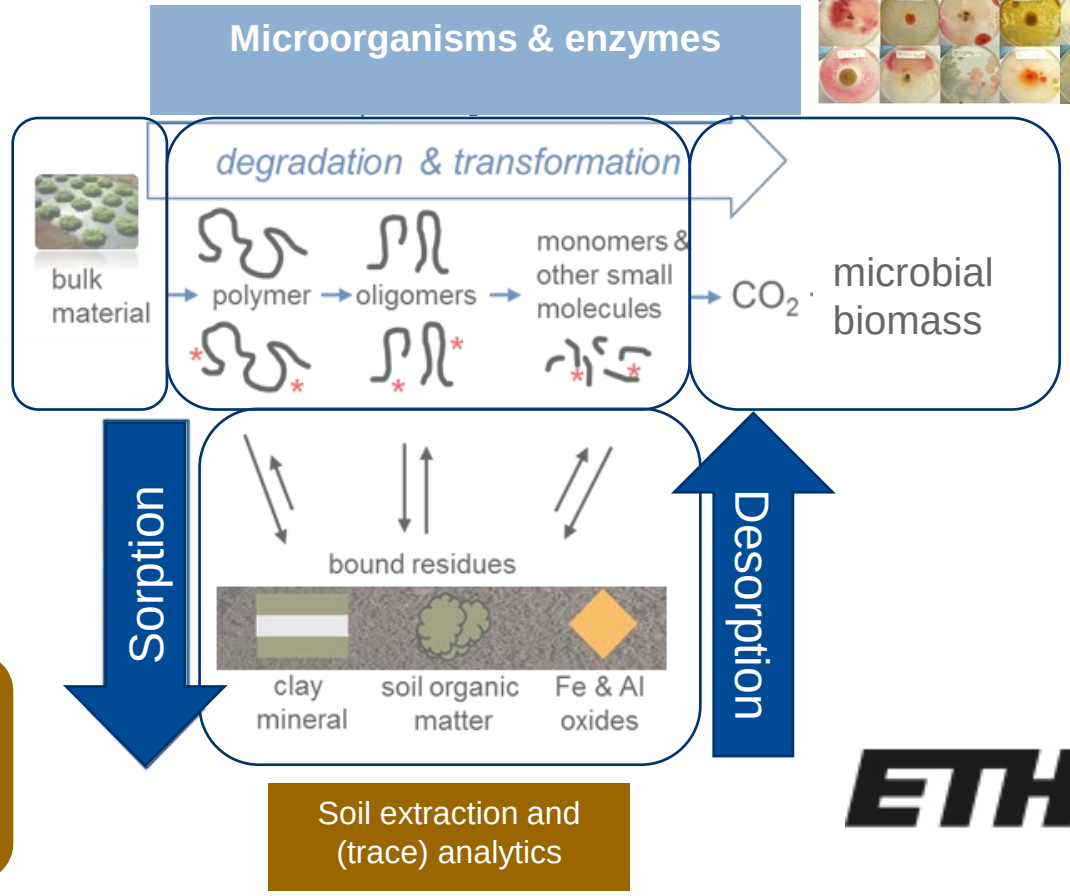


Biodegradation in soil

Decisive methods for understanding biodegradation in soil of ecovio® mulch film are established



700 organism identified



Nanoscale Secondary Ion Mass Spectrometry (NanoSIMS)

Respirometric measurements (O_2 demand, CO_2 evolution)

Cavity ring down spectroscopy (CRDS)

60 soils investigated

ETH zürich

For the first time fate of polymer from soil biodegradable mulch film can be followed

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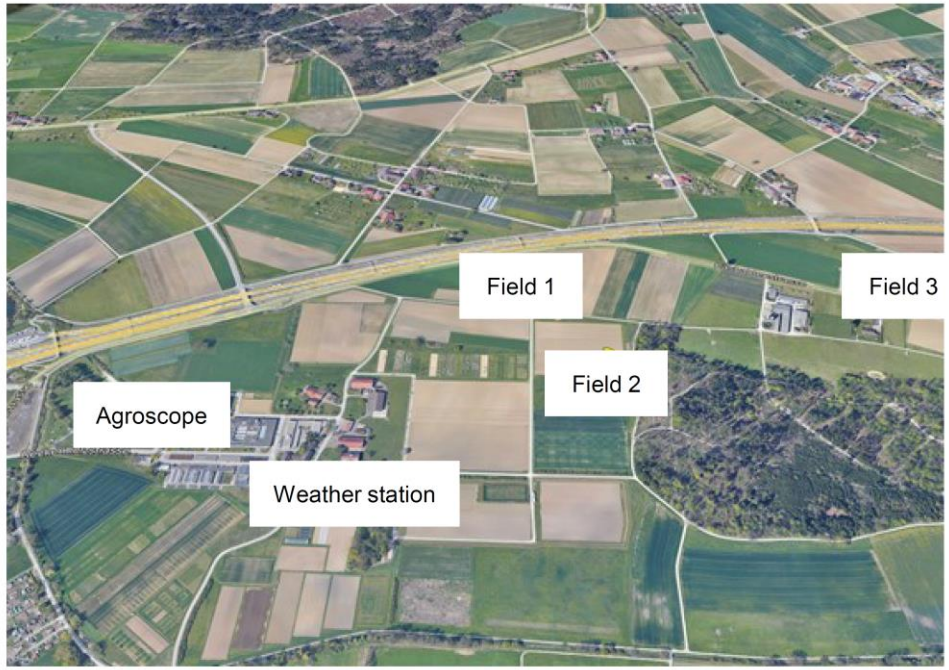
Biodegradation in soil

ecovio lab/field tests in different soils (ETH Zürich, Agroscope) 2020 - 2023

Background and experimental set-up

- Comparability of mulch film biodegradation in lab & field
- ecovio M2351 film samples used for studies
- Extraction-based biodegradation studies and DNA-extraction
- Respirometric/CO_2-evolution biodegradation studies and DNA extraction
- Sampling at different timepoints or at different level of biodegradation



- **Soil 1**: from a “Öko-Ausgleichsfläche”
- **Soil 2**: from a manure treated grassland
- **Soil 3**: from a normally treated agricultural field which just came off crop rotation

Mechanism of biodegradation related to polymer structure

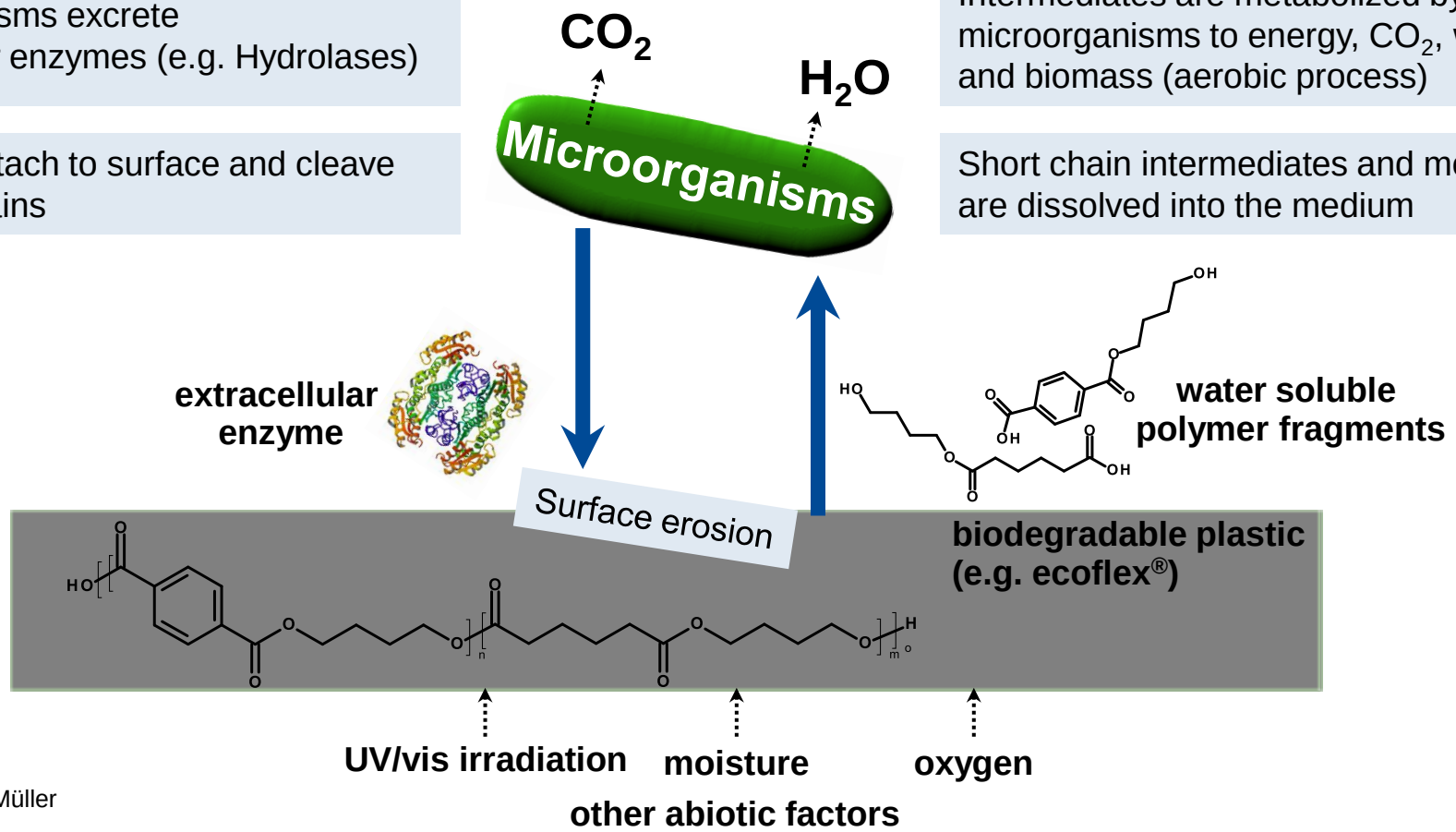
General mechanism of polymer biodegradation

Microorganisms excrete extracellular enzymes (e.g. Hydrolases)

Enzymes attach to surface and cleave polymer chains

Intermediates are metabolized by microorganisms to energy, CO_2, water and biomass (aerobic process)

Short chain intermediates and monomers are dissolved into the medium



adapted from R.J. Müller

Mechanism of biodegradation related to polymer structure

Breakdown of conventional vs. certified compostable plastics during composting

Conventional Plastics – e.g. LDPE

Fragmentation

Fragments

No biodegradation

Persistent microplastic

Fragmentation occurs via external processes such as mechanical treatment and creates persistent microplastic

Certified compostable plastics – e.g. ecovio®

Fragmentation during biodegradation

Fragments

Biodegradation

CO_2

Biomass, water & CO_2

Certified compostable plastics also fragment during composting, but the fragments are then completely biodegraded by microbes

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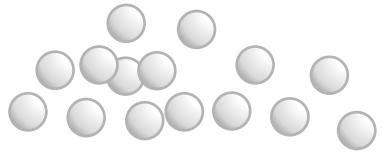
Mechanism of biodegradation related to polymer structure

Breakdown of conventional vs. certified compostable plastics during composting

A. Granules

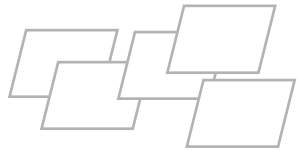
Micronized



3D micro-granules

B. Film

Micronized

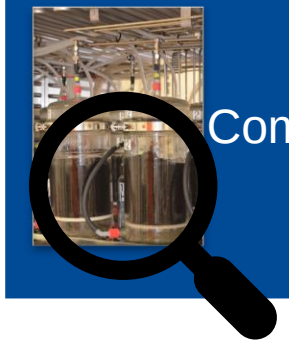


2D film pieces

C. Coated paper

Shredded

2D film-on-paper pieces



Composting

CO_2

carbon dioxide

+

biomass

+

water

Micronized = artificial fragmentation through physical milling

Mechanism of biodegradation related to polymer structure

How to develop microplastic analytics

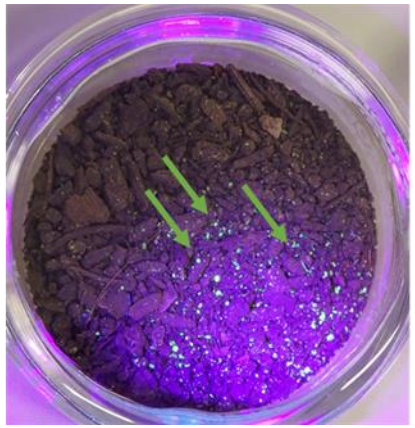
Challenge: complex compost matrix contains organics, inorganics, larger pieces of wood…

+

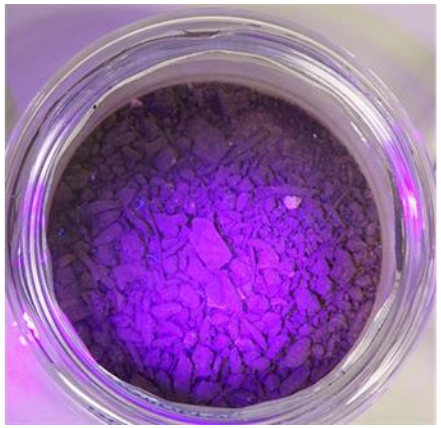
Industrial Composting

Sampling

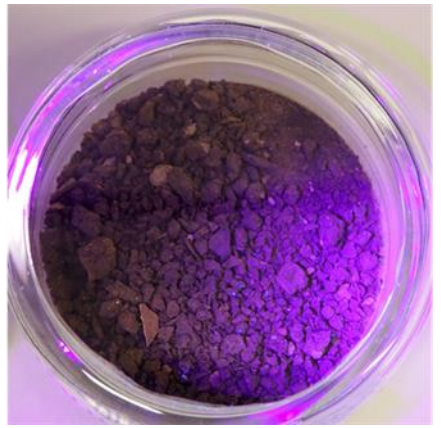
time point 0



6 % mineralization



50 % mineralization



end of the experiment

The use of a fluorescent labelled materials allow the training of analytical methods

Mechanism of biodegradation related to polymer structure

Microplastic extraction methods

Pfohl *et al. Microplastics and Nanoplastics* (2021) 1:8
https://doi.org/10.1186/s43591-021-00009-9

Microplastics and Nanoplastics

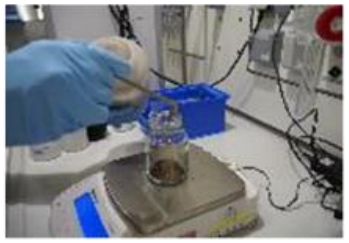
Microplastic extraction protocols can impact the polymer structure

Patrizia Pfohl[1], Christian Roth[1], Lars Meyer[1], Ute Heinemeyer[1], Till Gruendling[1], Christiane Lang[1], Nikolaus Nestle[1], Thilo Hofmann[2], Wendel Wohlleben[1] and Sarah Jessl[1,3*]

Particle extraction

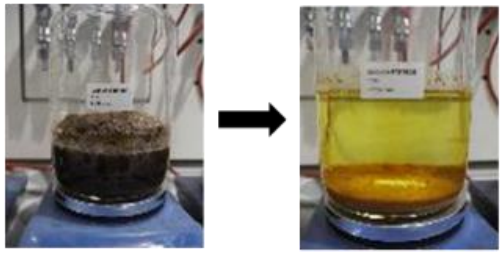
Compost + Microplastic particles in bottle & tumbler

Sampling + 30 mL Millipore water

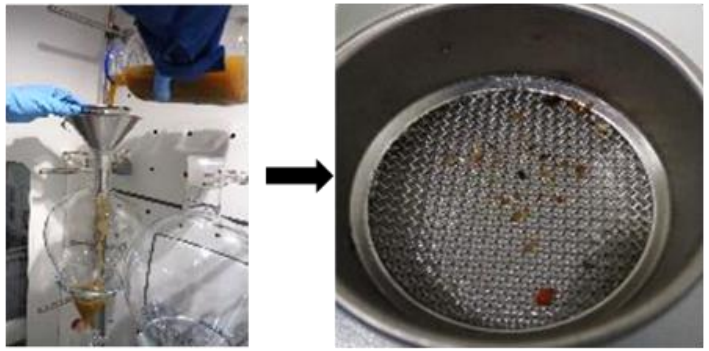


Ultrasonication (15 min)

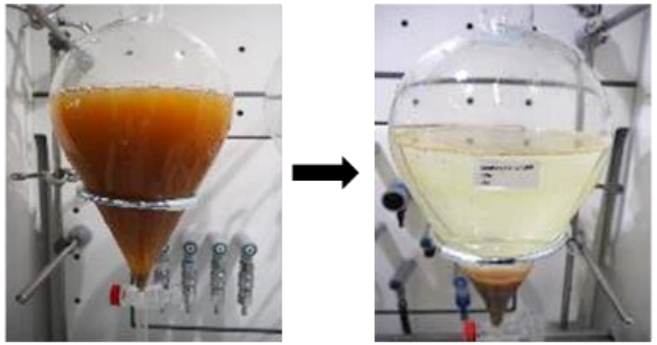
Oxidation (inorganics included) for removal of organics



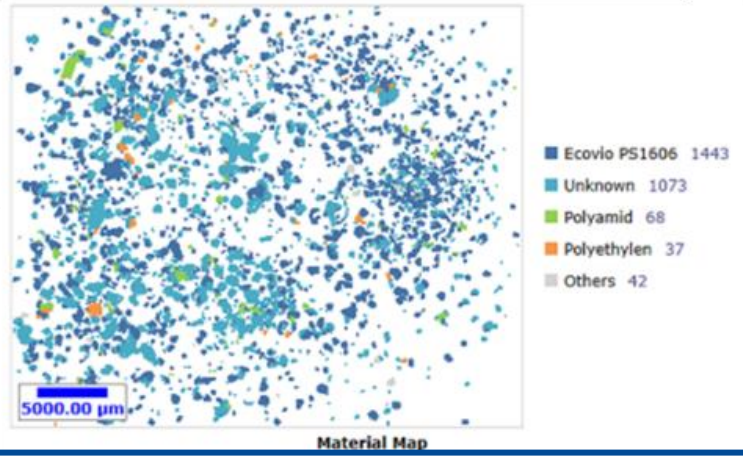
Sieving: Removal of components > 1 mm



Density separation (removal of oxidation residue, inorganics)



µ-Raman microscopy „particle hunter“ software



All types of microplastics extracted and number/size/shape/identity of fragments determined

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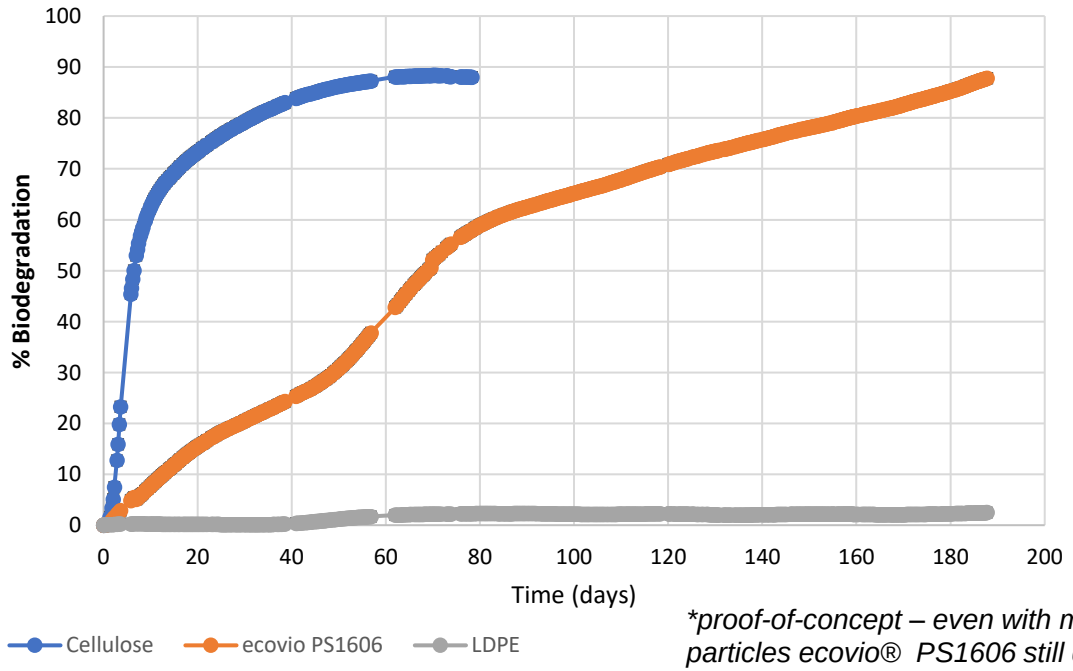
Mechanism of biodegradation related to polymer structure

Can Biodegradable Materials Create Persistent Microplastic?

ecovio® PS1606 Biodegradation
(330µm particles*)

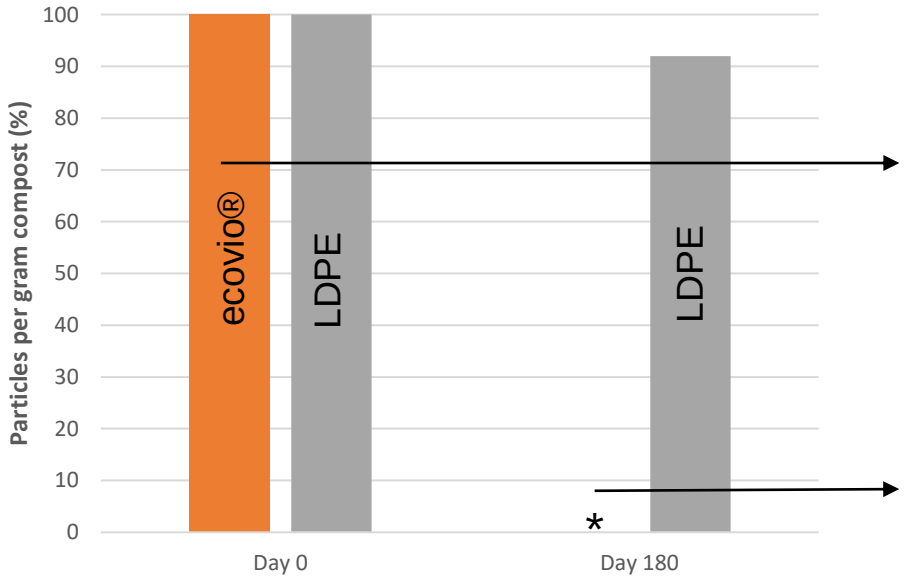
% biodegradation in compost at 55°C (industrial conditions):



*proof-of-concept – even with much larger particles ecovio® PS1606 still degrades

Measuring labelled-ecovio® /paper particles during composting

Number of labelled particles in compost:



* Limit of detection: 3 µm

After industrial composting, ecovio® PS1606 is fully biodegraded and no labelled ecovio® microparticles remain in compost

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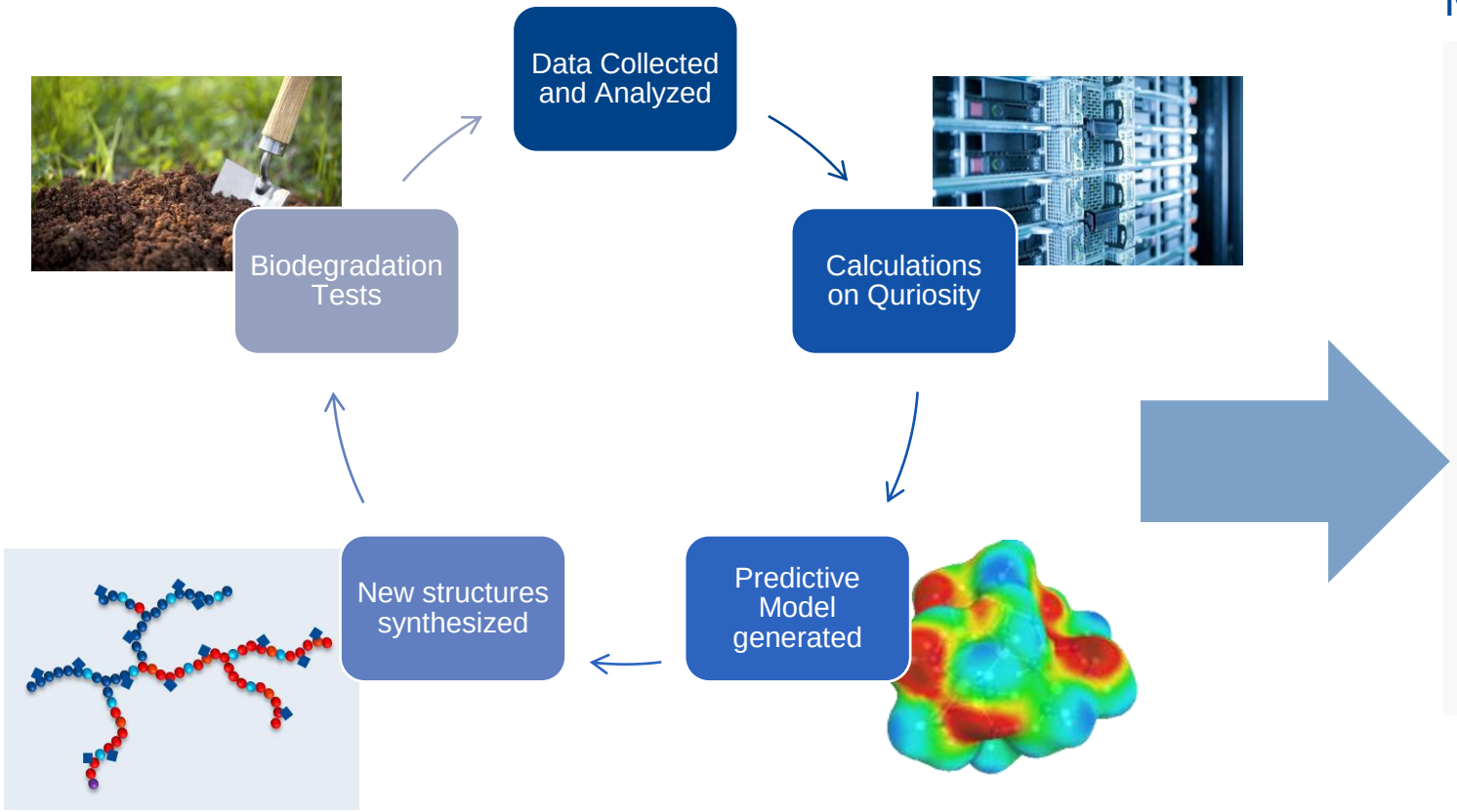
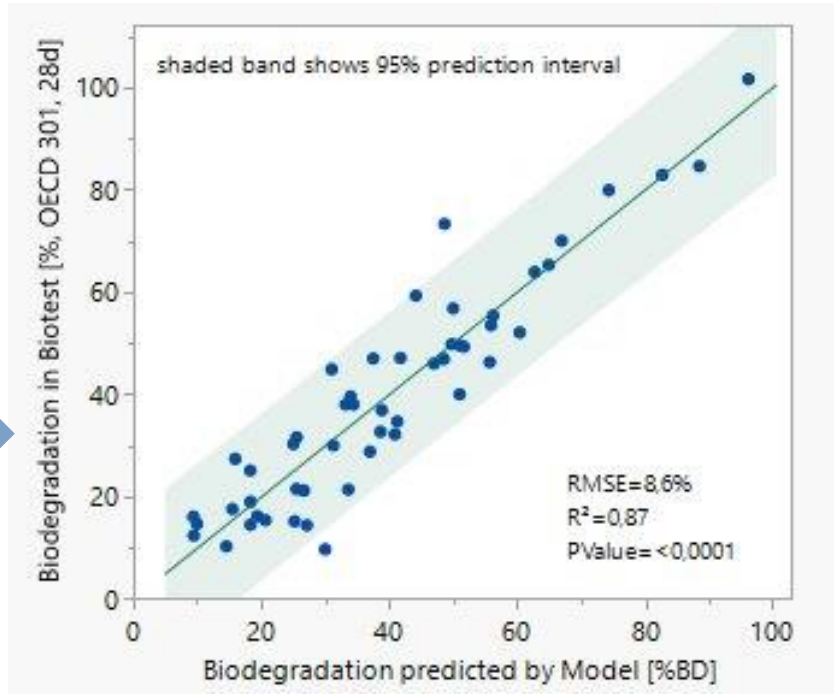
Approach with new tools

Predictive biodegradation modelling

How is a Model Developed?



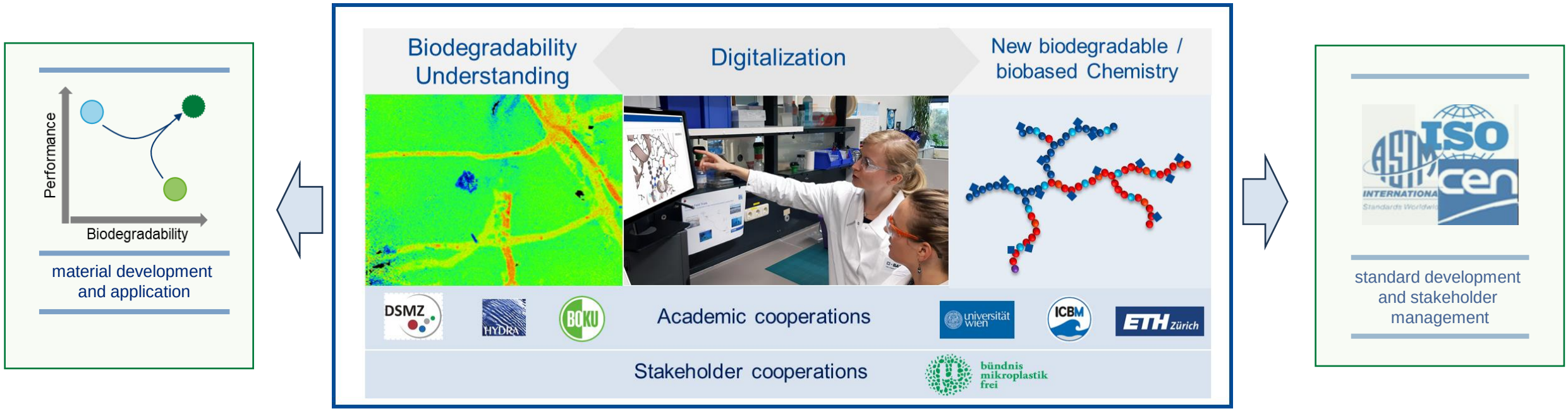
Model correlation with lab tests:



A novel machine learning model which accurately predicts the biodegradation of polymers in different end-of-life environments

Research biodegradable and biobased materials

New methods developed by BASF and cooperation partners to show the biodegradation of certified biodegradable materials



Know how is provided and applied to certified soil biodegradable mulch film and certified compostable paper-ecovio packaging contributing to a circular economy

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