PRESERVE Training
Biodegradation: one concept, many environments

May 24th 2024, Online

Gaëlle Cavalié, Steven Verstichel

Topics

- Normec OWS
- Biodegradation: the basics Bioplastics
    - Biodegradation in various environments & associated standards
        - Managed environments
        - Open/unmanaged environments
- EU projects results
- Q&A

Normec OWS as a company

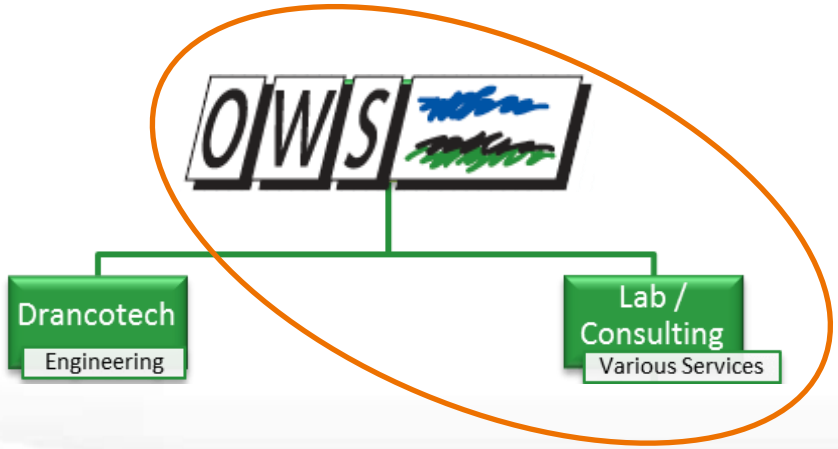
Normec OWS

History

1984 Created as spin-of from Ghent University:
Initial focus on anaerobic digestion of biowaste (Dranco)

1990 First laboratory to develop biodegradability test

2020 Acquired by Normec Group



Normec OWS

Normec OWS

Today

A one-stop lab for biodegradability & compostability testing

Strictly independent

No conflict of interests …

Recognized by certification bureaus worldwide

Tüv AU-BE, DIN CERTCO, BPI, ABA, JBPA, …

Normec OWS

Today

Biggest capacity +3500 reactors ⟷ short lead times	Headquarters in Ghent – BE
• Biodegradation, Composting, Disintegration, Ecotoxity, … • Testing & Consulting • > 35 years of experience!	• Affiliate lab in Kettering-Ohio, USA • >100 employees • Turnover >10 Mio € • Serving >1500 accounts worldwide
Member of several standardization agencies, certification committees & industrial associations	**Participant into major EU projects**

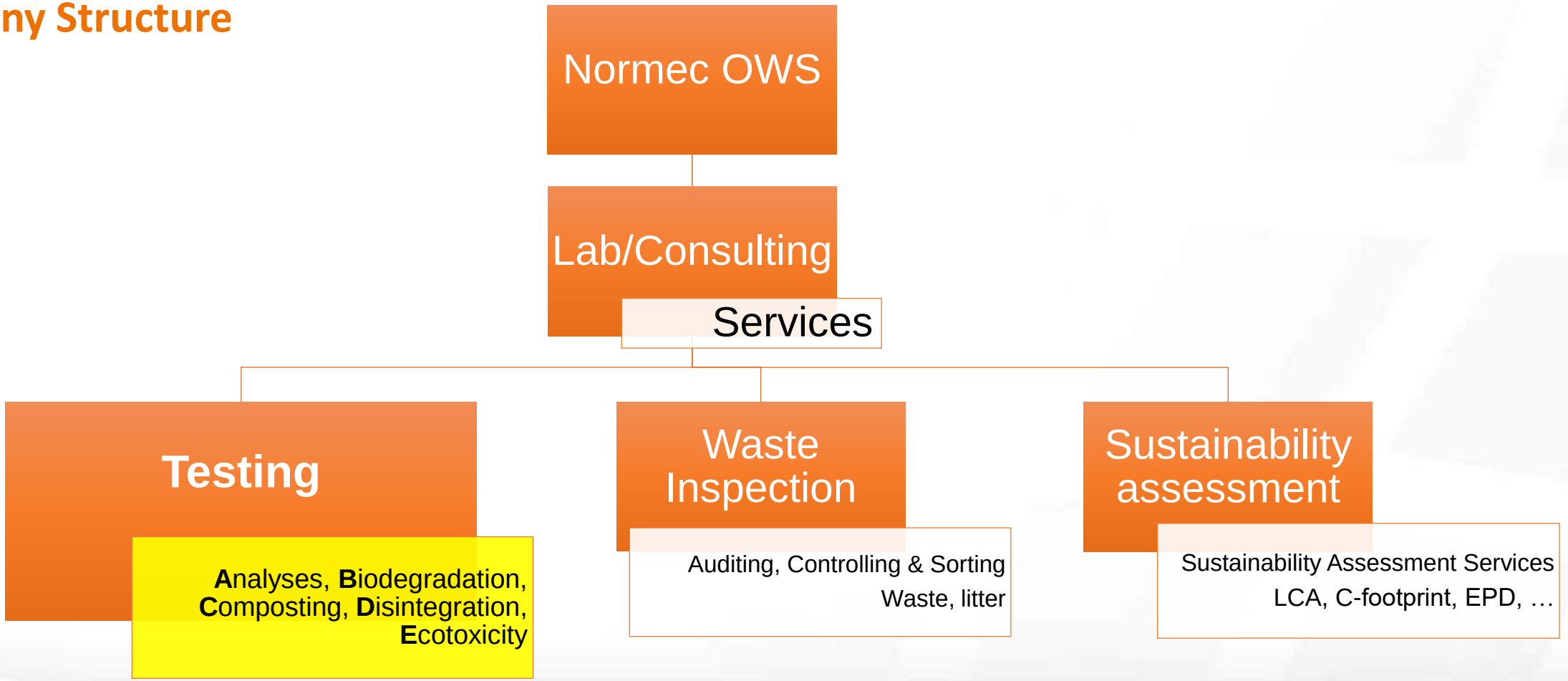
Markets served

Base Polymers	Paper and board	Chemicals	Packaging	Research Labs & Universities
Cosmetics	Textiles	Agriculture	Government	Consumer goods

Normec OWS serves many customers in each of these markets across the world

Normec OWS

Company Structure



Analyses, Biodegradation, Composting, Disintegration & Ecotoxicity

Biodegradability
Compost
Soil
Fresh water
seawater
Landfill - AD

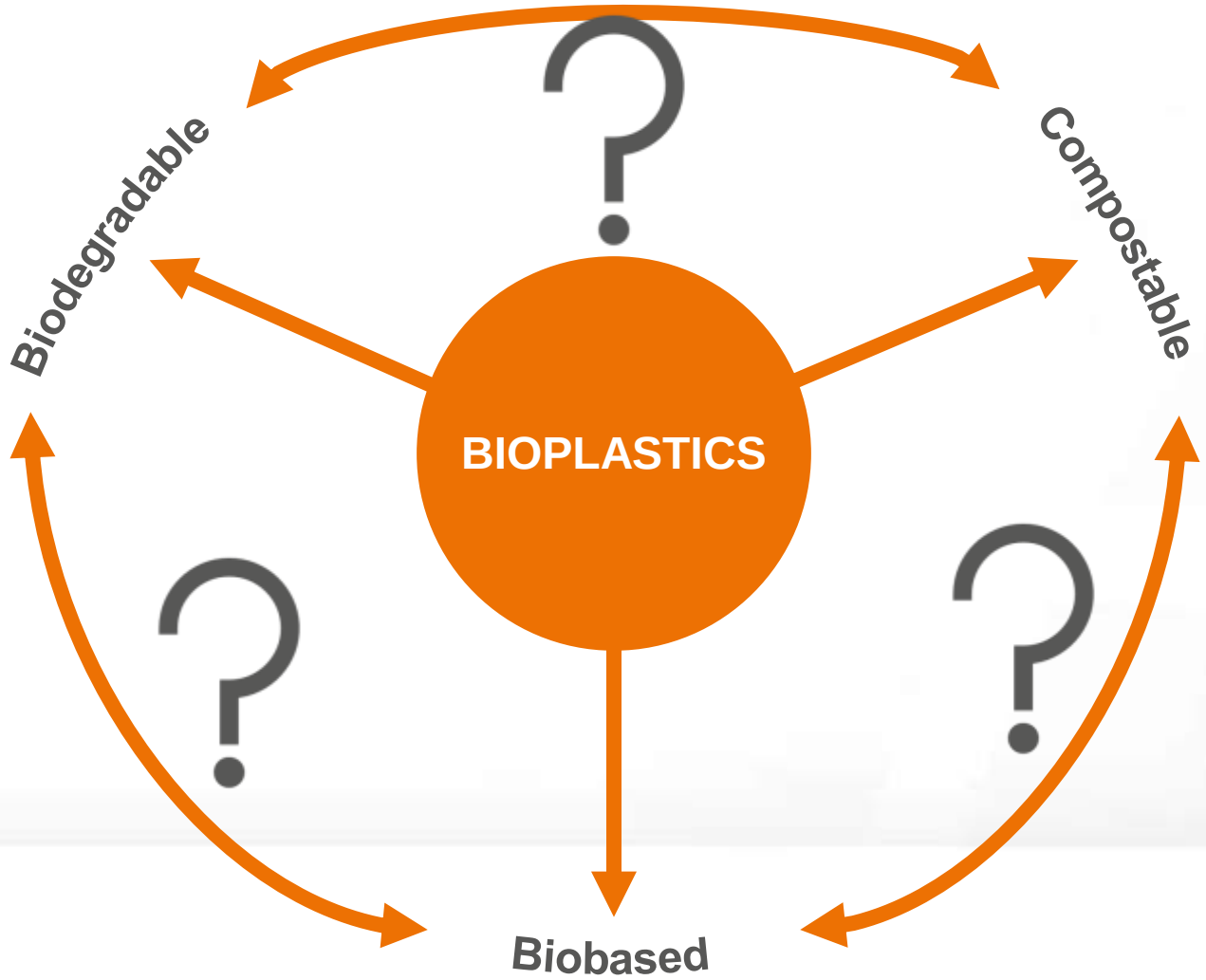
Compostability
Industrial
Home

Consultancy
Contract
research
Workshops

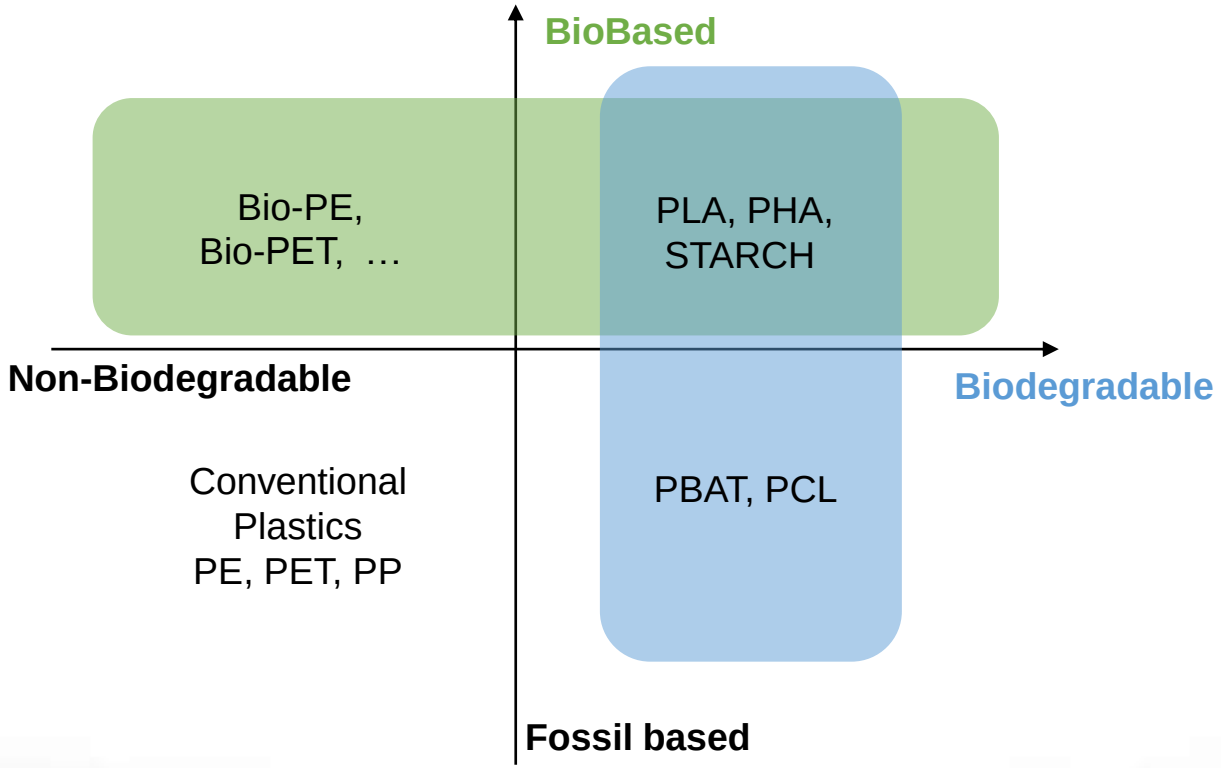
Ecotoxicity
Terrestrial
Aquatic
Microbial

Bioplastics: what's in a name?

Bioplastics: what's in a name?



Biobased vs. Biodegradable vs. Bioplastic



Biobased	Biodegradable
Origin of material	End-of life of material
Renewable vs non-renewable (fossil, petrochemical)	Chemical conversion of (organic) carbon into CO_2 and/or CH_4
Biobased ≠ Biodegradable **Petrobased ≠ non-biodegradable**	
Bioplastics Can be **biobased and/or biodegradable** Conventional plastics are fossil-based and not biodegradable	

Biodegradation

Biodegradation

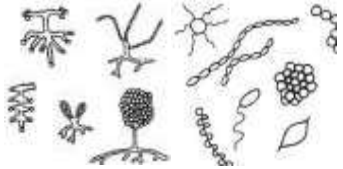
a biological process

Oxygen input

Energy output (heat)

Biodegradation

(micro-organisms)



Organic matter

Organic **C**arbon
(plants, fruits, …)

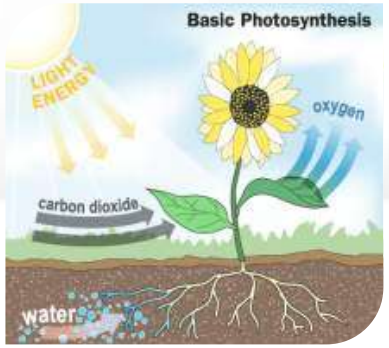
CO_2, water, **humus, biomass**

Photosynthesis

(plant cells, …)

Energy intake (sun)

Oxygen is released



Biodegradation

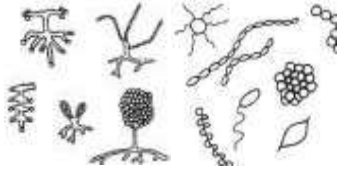
a biological process

~~Oxygen input~~

Energy output (heat)

Biodegradation

(micro-organisms)



Organic matter

Organic **C**arbon
(plants, fruits, …)

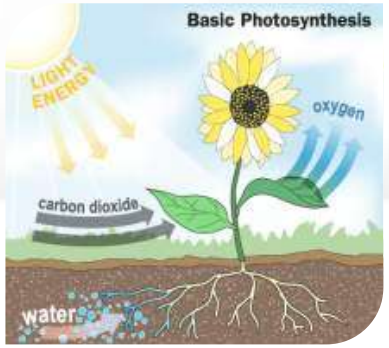
CH_4 + **CO_2** , water, **humus, biomass**

Photosynthesis

(plant cells, …)

Energy intake (sun)

Oxygen is released



Biodegradation

a (bio)chemical process

$$C_{organic} + O_2 \Rightarrow \ldots \Rightarrow \ldots \Rightarrow CO_2 + H_2O + C_{residual} + C_{biomass}$$

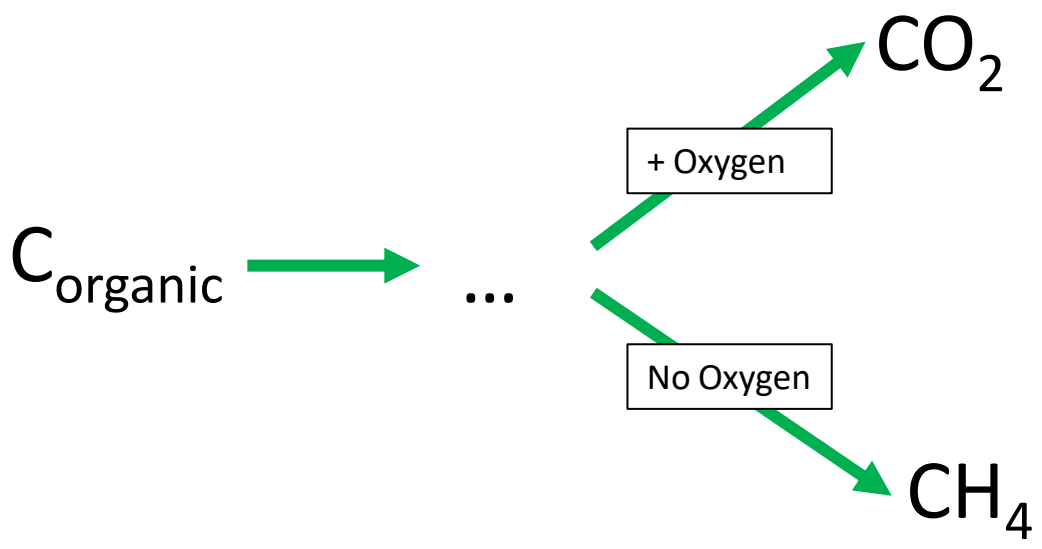
$$C_{organic} + \cancel{O_2} \Rightarrow \ldots \Rightarrow \ldots \Rightarrow CH_4 + CO_2 + H_2O + C_{residual} + C_{biomass}$$

Note: not all organic carbon is converted into CO_2 (± CH_4)

Pass levels ≥90% organic carbon is converted into CO_2 (± CH_4)

Biodegradation

☑ = a (bio)chemical process



☒ a physical process

- **= Disintegration**
- Fragmentation
- Molecular weight reduction
- Loss of technical characteristics
- Particles still visible (eye or microscope)

Biodegradation

Various Environments

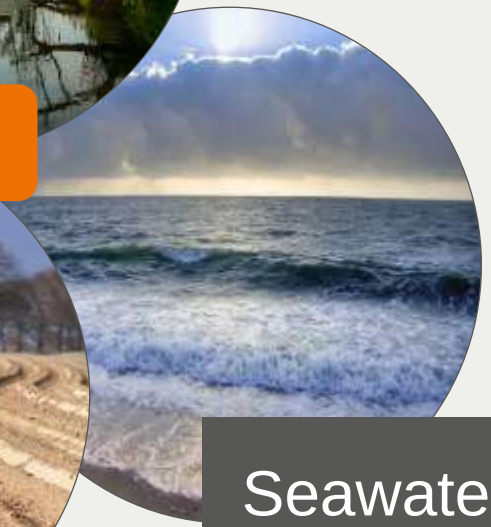
Industrial Compost

Fresh water

Aerobic

Home Compost

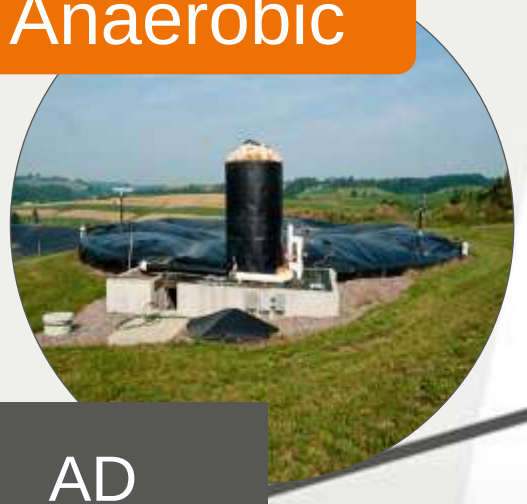
Soil



Seawater

Landfill

Anaerobic



AD

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Aggressiveness of environment

Biodegradation behavior varies from one environment to the other (no extrapolation possible)

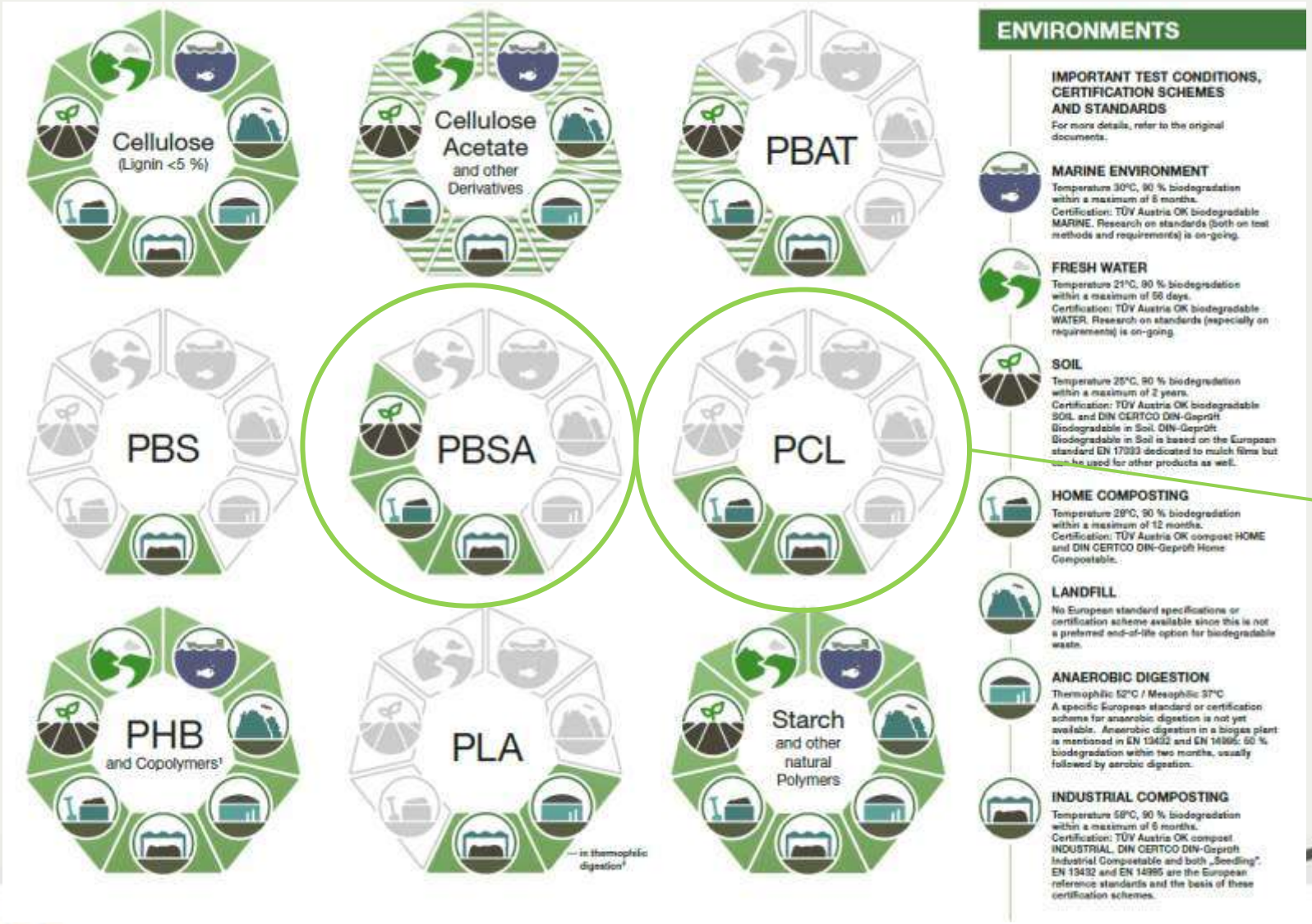
	Industrial compost	Home compost	Soil	Fresh water	Marine water	Anaerobic digestion
Standard	ISO 14855	ISO 14855	ISO 17556	ISO 14851	ISO 23977	ASTM D5511
Temperature	High (60–70°C)	Low (21–30°C)				High/low
Species	Fungi + Bacteria + Actinomycetes			Only bacteria (some filamentous fungi)		Multiple Bacteria

Decreasing aggressivity



Always specify environment where material is biodegradable

Biodegradation depends on environment

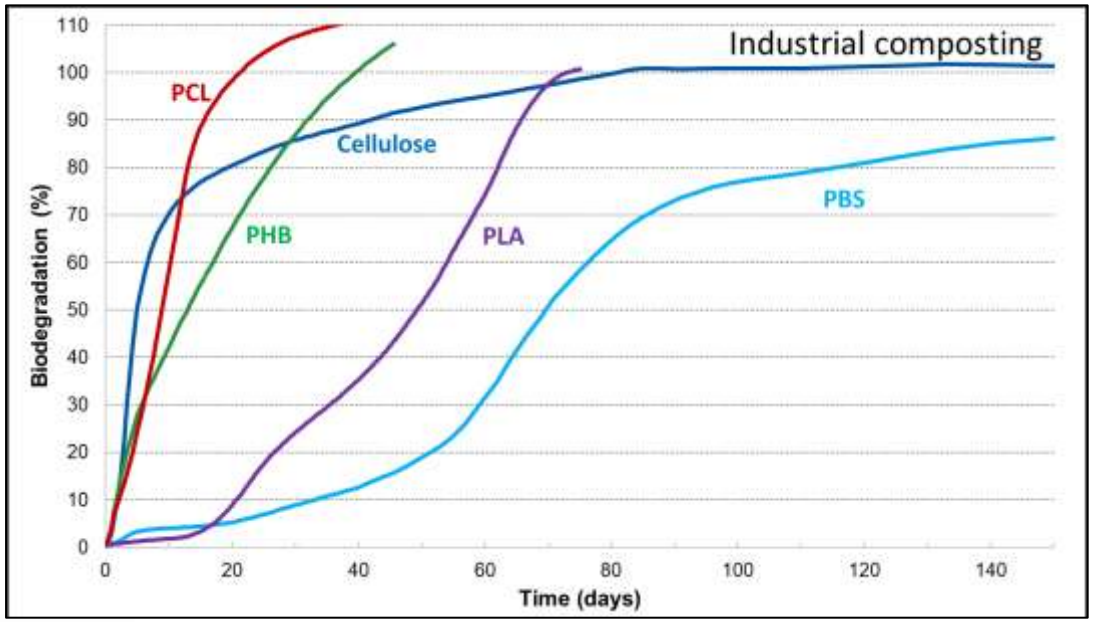


PCL & PBSA have now been tested in more environments

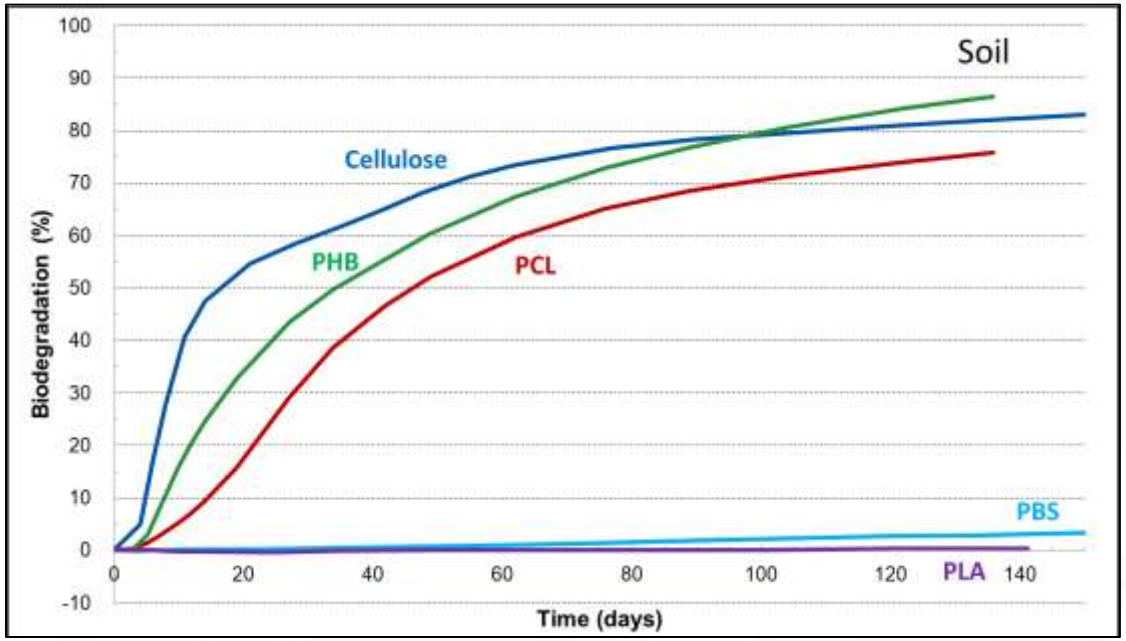
Biodegradation depends on environment

Example

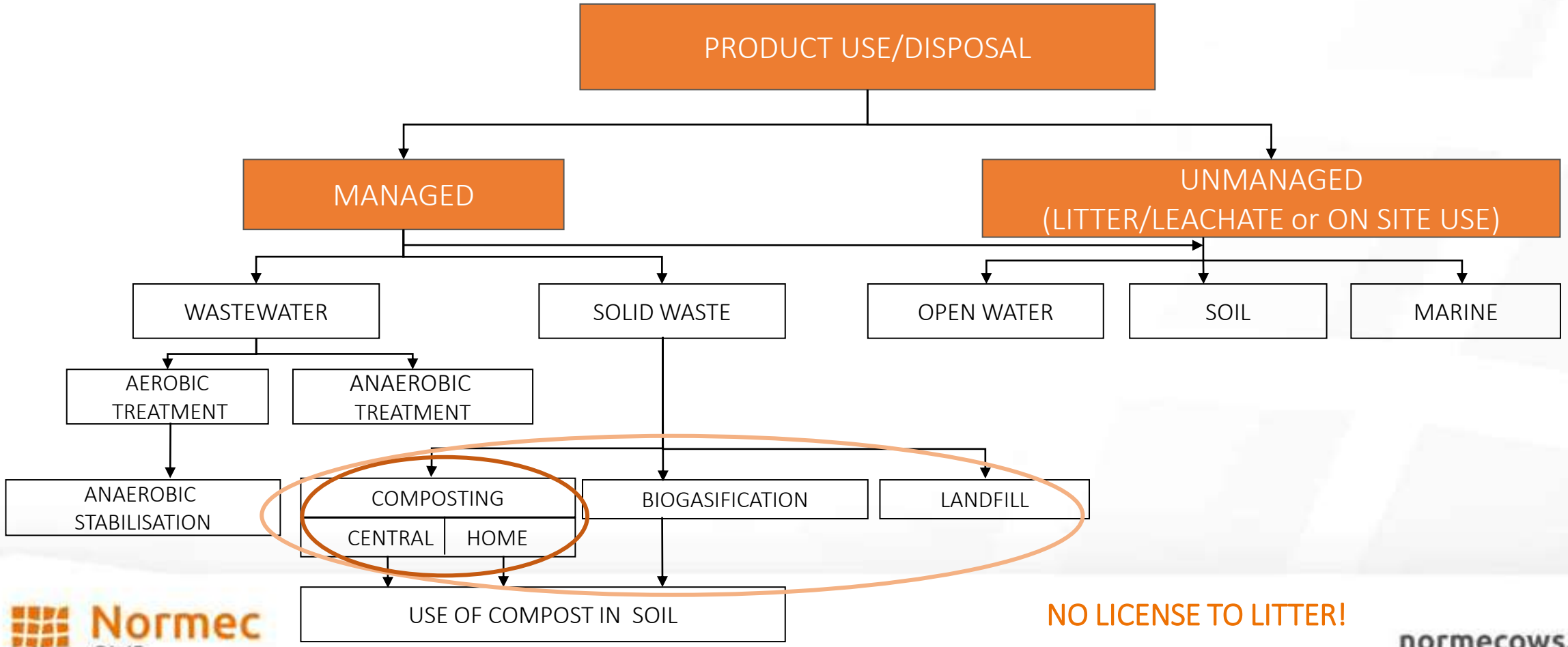
Industrial composting



Soil



Biodegradation in controlled environments: compost



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Composting versus Biodegradation

Environmental Safety

- Material characterization
- Ecotoxicity

+

Degradation

- Biodegradation
- Disintegration

Composting versus Biodegradation

Environmental Safety

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Degradation

- Biodegradation
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1. Characteristics of material

Chemical analysis: heavy metals , fluorine

Analysis	Limit values			
	Europe EN 13432 (2000)	France NF T51-800 (2015)	USA** ASTM D6400 (2023)	Canada CAN/ BNQ 0017-088 (2010)
Heavy metals*				
As	≤ 5	≤ 5	< 20.5	< 9.5
Cd	≤ 0.5	≤ 0.5	< 19.5	< 2.5
Co	-	≤ 38	-	< 19
Cr	≤ 50	≤ 50	-	< 132.5
Cu	≤ 50	≤ 50	< 750	< 94.5
Hg	≤ 0.5	≤ 0.5	< 8.5	< 0.5
Mo	≤ 1	≤ 1	-	< 2.5
Ni	≤ 25	≤ 25	< 210	< 22.5
Pb	≤ 50	≤ 50	< 150	< 62.5
Se	≤ 0.75	≤ 0.75	< 50	< 2
Zn	≤ 150	≤ 150	< 1400	< 231.5
Fluorine				
F	≤ 100	≤ 100	-	-

Inks often contain high concentrations on heavy metals

Composting versus Biodegradation

Environmental Safety

- Material characterization
- Ecotoxicity

+

Degradation

- Biodegradation
- Disintegration

2. Ecotoxicity

What is it?

- Ecotoxicity testing evaluates the **potential toxic effect of residuals**, which are left behind after composting. These can potentially inhibit plant growth or diminish the survival of soil fauna (earthworms).
- Plant toxicity testing is a part of all standards for **industrial and home compostability** and prescribes the use of **two plant species**, according to the OECD 208 test method.
- **Earthworm toxicity testing**, however, is **only** required for AS 4736 & AS 5810 certification in **Australia** in accordance with the OECD 207 test method.

2. Ecotoxicity

Example results – plant toxicity (germination rate & dry weight)

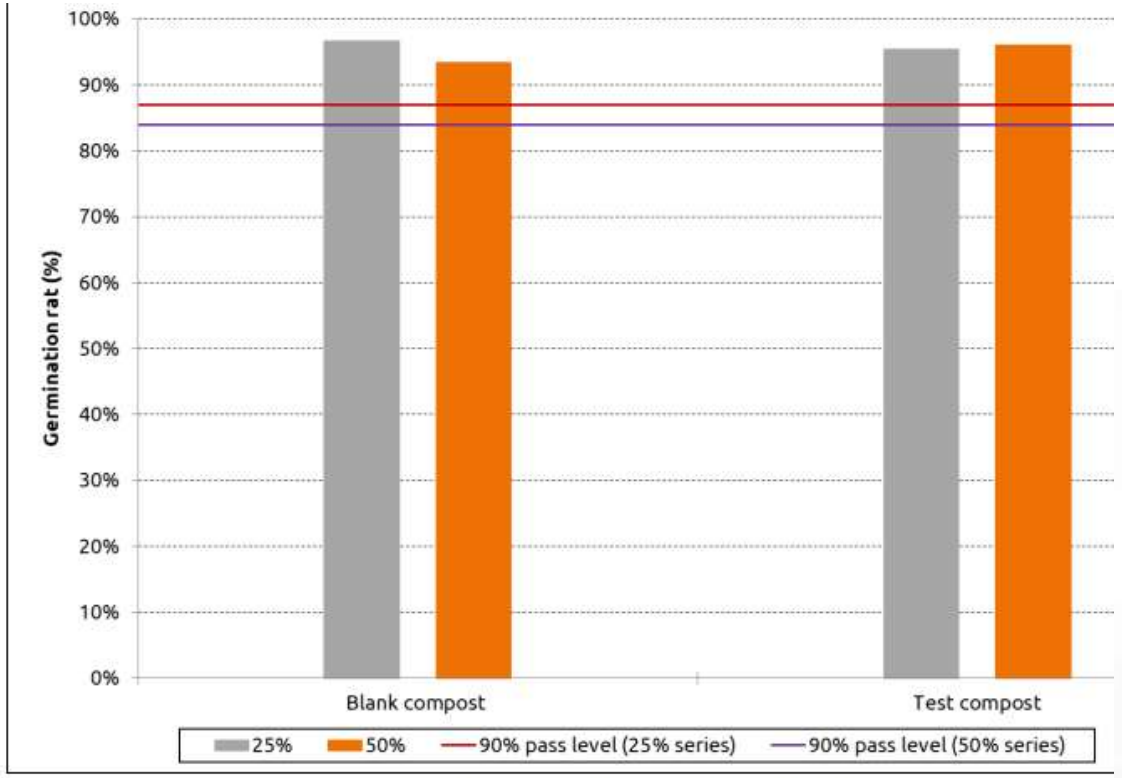

Figure 1. Average germination rate
(as percentage to the total amount of seeds added at start)

2. Ecotoxicity

Example results – earthworms (survival rate & average weight)

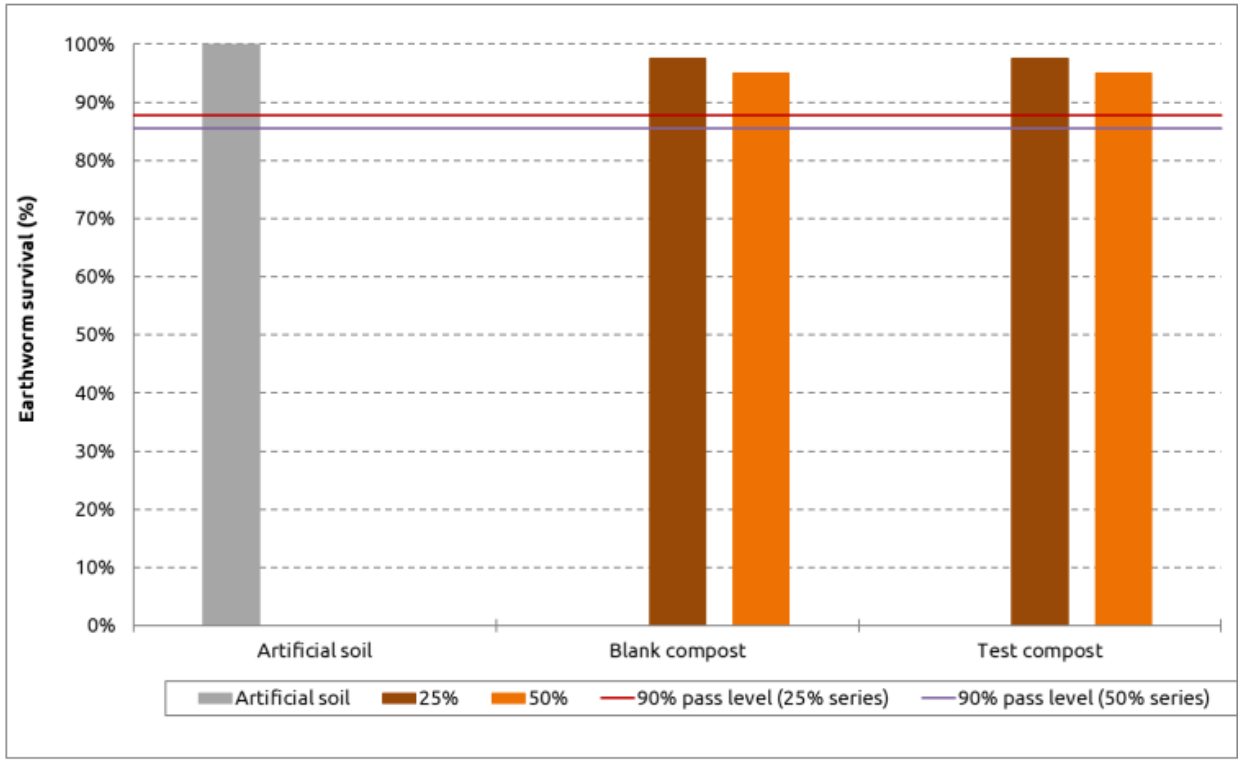

Figure 1. Average survival of earthworms

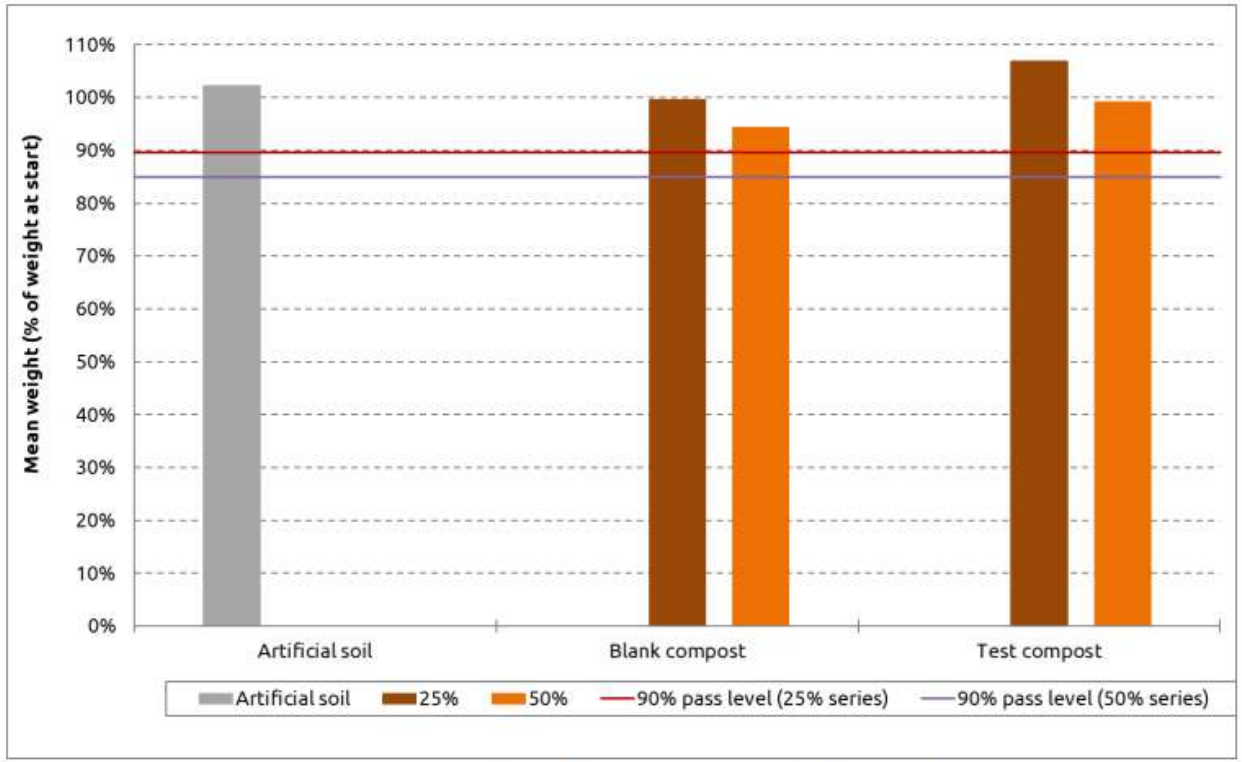

Figure 2. Average weight of earthworms (as % of weight at start)

Composting versus Biodegradation

Environmental Safety

- Material characterization
- Ecotoxicity

+

Degradation

- ~~Biodegradation~~
- Disintegration

3. Disintegration: industrial & home

Principle

- **Influenced by shape, thickness, grammage, coating, print, physical aspects**
- Method:
  - ISO 16929 (pilot scale 200L divided in 2 compartments) – industrial
  - ISO 20200 – home
- Pass level:
  - minimum 90% (in weight) must go through a 2mm sieve in maximum 12 weeks – industrial
  - minimum 90% in maximum 26 weeks – home

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3. Disintegration: industrial & home

Example results

Composting versus Biodegradation

Environmental Safety

- Material characterization
- Ecotoxicity

+

Degradation

- Biodegradation
- Disintegration

4. Biodegradation – industrial & home

Principle

- **Milled** test material is put into mature compost (inoculum)
- Temperature:
  - 58°C industrial
  - 28 °C home
- Mesurement of biodegradation:
  - TOC (total organic carbon) at start
  - Conversion into CO2 (KOH absorption and titration)
- **Monitoring of CO_2 production:**
  - test compost
  - reference compost (cellulose)
  - blank compost
- Pass level:
  - min. 90% in max. 6 months – industrial
  - min. 90% in max. 12 months – home

Summary: certification for composting

Industrial Compostability

- Chemical Characteristics
- Biodegradation at 58°C (90% in 6 months)
- Disintegration in industrial compost (90% in 12 weeks)
- Ecotoxicity (plants but sometimes also earthworms and/or micro organisms)

Home Compostability

- Chemical Characteristics
- Biodegradation at 28°C (90% in 1 year)
- Disintegration in home compost (90% in 26 weeks)
- Ecotoxicity (plants but sometimes also earthworms and/or micro organisms)

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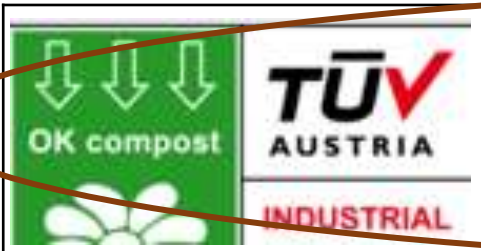
Industrial Composting – Certification logos

OK compost INDUSTRIAL & HOME **Tüv AUSTRIA**	DIN GePrüft, Industrial& Home Compostable **DIN CERTCO**	Seedling **European Bioplastics**	Industrial compostable **BPI**	Industrial & Home compostable **ABA**
OK compost HOME **Tüv AUSTRIA**		-	TO COME (expected end of 2024)	

Standards	Certification scheme
Theory / Legislation	Practice / Control system Based on standards + (own) certification scheme

Industrial Composting – Certification logos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Standards	Certification scheme
Theory / Legislation	Practice / Control system Based on standards + (own) certification scheme

Industrial Composting

Standards

	ISO	CEN	ASTM	STANDARDS Australia
Plastics	ISO 17088	EN 14995	ASTM D6400	AS 4736
Packaging	ISO 18606	EN 13432		
Paper coating			ASTM D6868	
Paper			ASTM D8410	

Distinction:

- Specification standards: define which criteria have to be evaluated and what are the pass levels. VERSUS
- Test methodologies standards: for each test, specify the exact test conditions & measurements methods.

Industrial Composting – Certification logos

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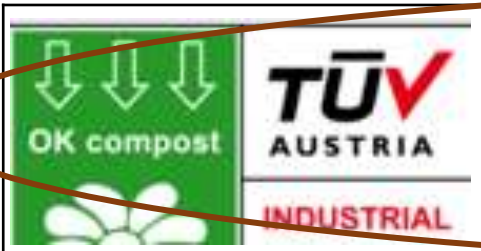
Industrial Composting – Certification logos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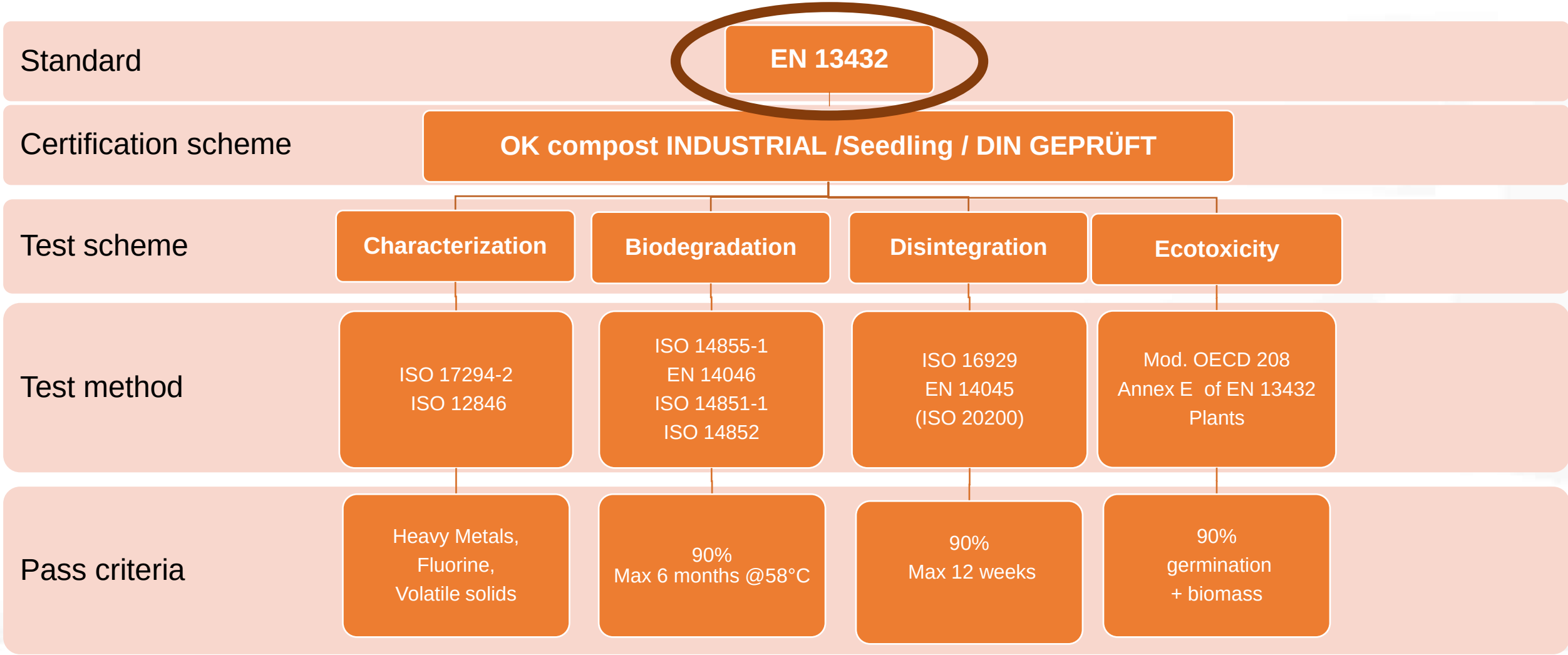
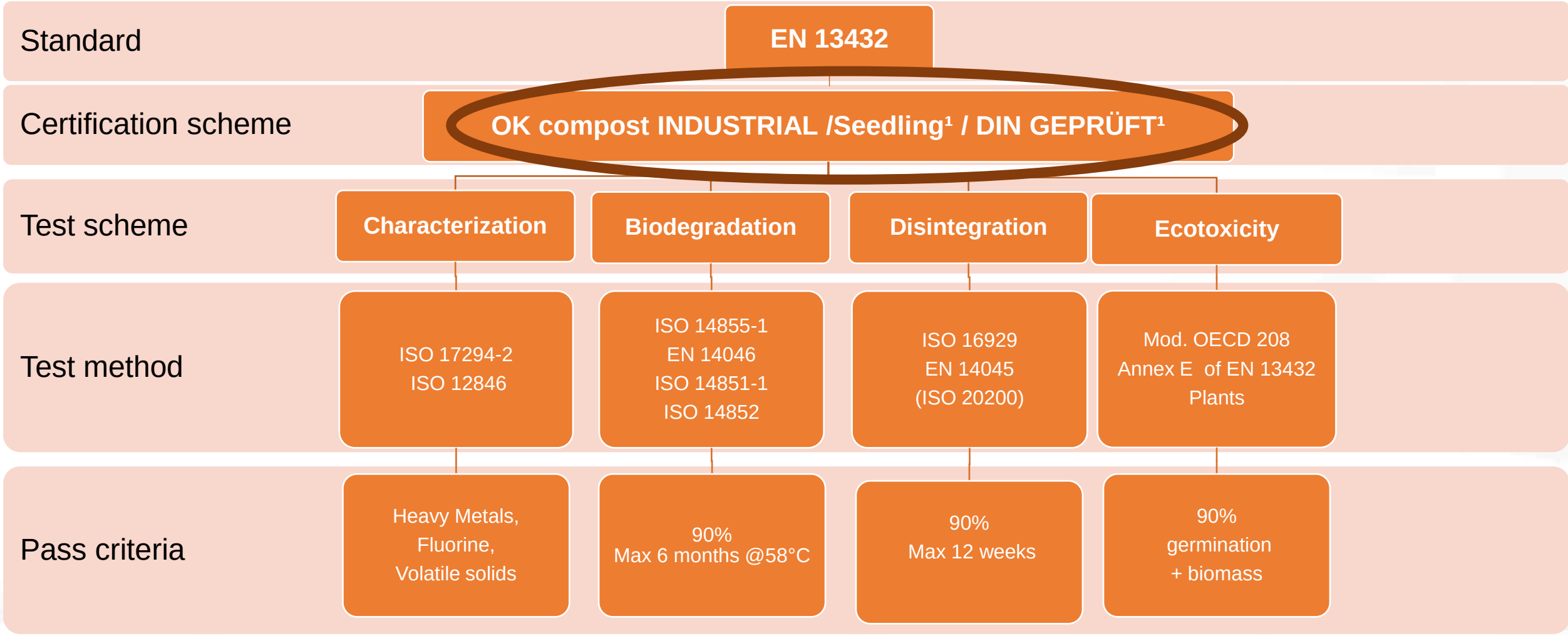
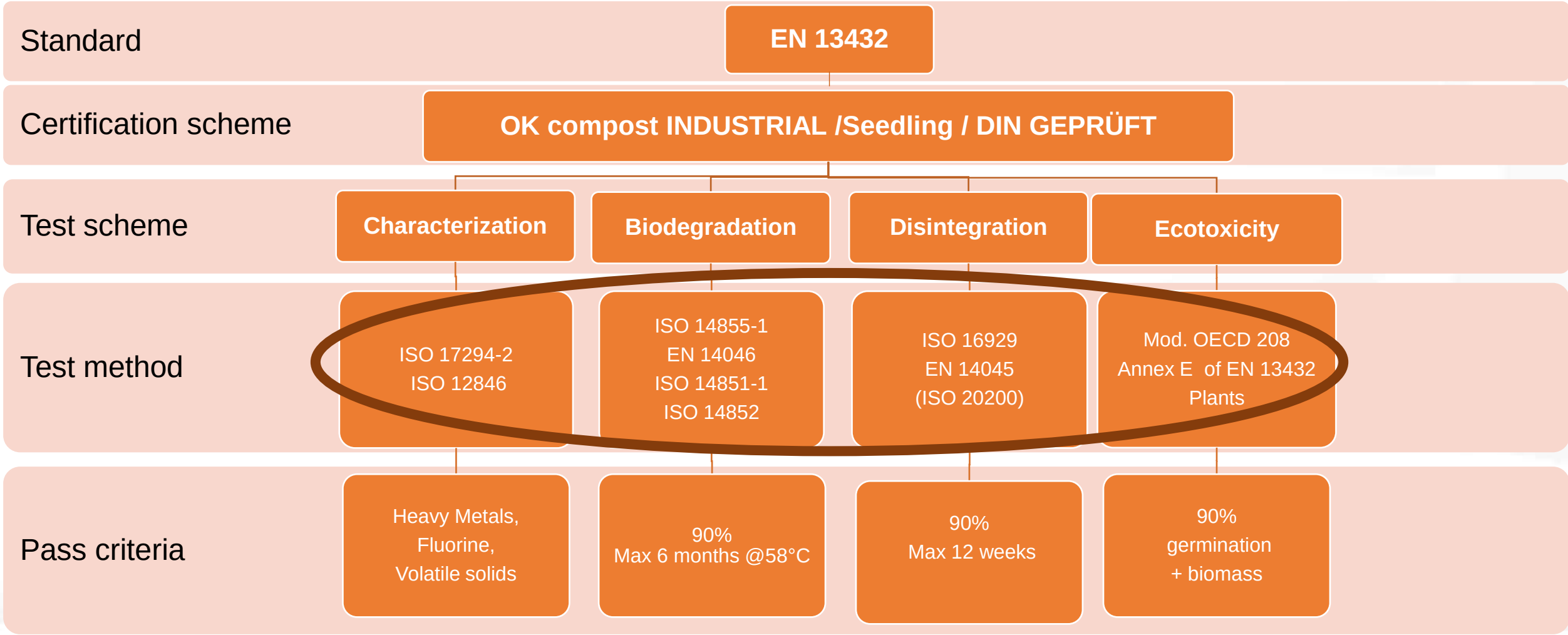


Industrial Composting

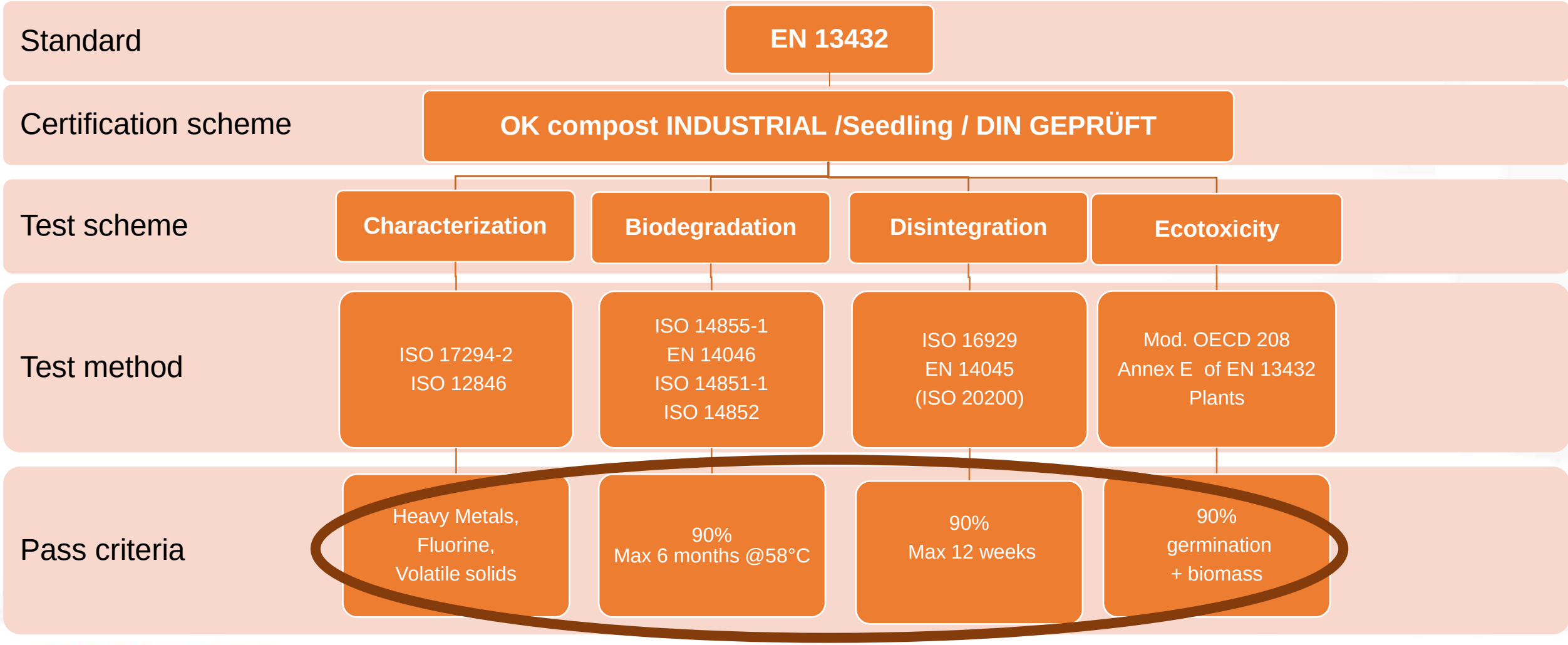


[1] minor differences vs EN 13432 vs. ISO 17088 / ISO 18606 vs. AS 4736 vs ASTM D 6400 / ASTM D 6868

Industrial Composting



Industrial Composting



Home Composting – Certification logos

				
		-	TO COME (expected end of 2024)	
OK compost INDUSTRIAL & HOME **Tüv AUSTRIA**	DIN GePrüft, Industrial& Home Compostable **DIN CERTCO**	Seedling **European Bioplastics**	Industrial compostable **BPI**	Industrial & Home compostable **ABA**

Standards → **Certification scheme**

Theory / Legislation	Practice / Control system Based on standards + (own) certification scheme

Home Composting – Certification logos

				
		-	TO COME (expected end of 2024)	
OK compost INDUSTRIAL & HOME **Tüv AUSTRIA**	DIN GePrüft, Industrial& Home Compostable **DIN CERTCO**	Seedling **European Bioplastics**	Industrial compostable **BPI**	Industrial & Home compostable **ABA**

Standards → **Certification scheme**

Theory / Legislation

Practice / Control system
Based on standards + (own) certification scheme

Home Composting

Standards

	afnor NORMALISATION	cen	STANDARDS Australia
Plastics	NF T 51-800		AS 5810
Packaging		EN 17427	

Distinction:

- Specification standards: define which criteria have to be evaluated and what are the pass levels. VERSUS
- Test methodologies standards: for each test, specify the exact test conditions & measurements methods.

Home composting - specifications

Standards

Similar to Industrial Composting, yet at ambient temperature (28°C)

Standard specification	Characterization	Biodegradation	Disintegration Quantitative*	Toxicity		
		Max. 12 months	Max 6 months	Plants	Earthworms	Nitrification inhibition
Australia AS 5810	X	X	X Modified ISO 20200** lab scale	X	X	-
France NF T 51-800	X	X	X Modified ISO 20200** lab scale	X	-	-
Europe EN 17427	X	X	X NEW: EN 17428**	X	X	X

* Qualitative testing in compost at ambient temperature is accepted when > 90% disintegration is obtained in a quantitative pilot-scale composting test, performed under industrial composting conditions.

** subtle differences between both ISO 20200 and ISO 16929! – **TUV OK compost HOME is referring to Modified ISO 20200 (March 2024)**

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Composting

co-benefit effects

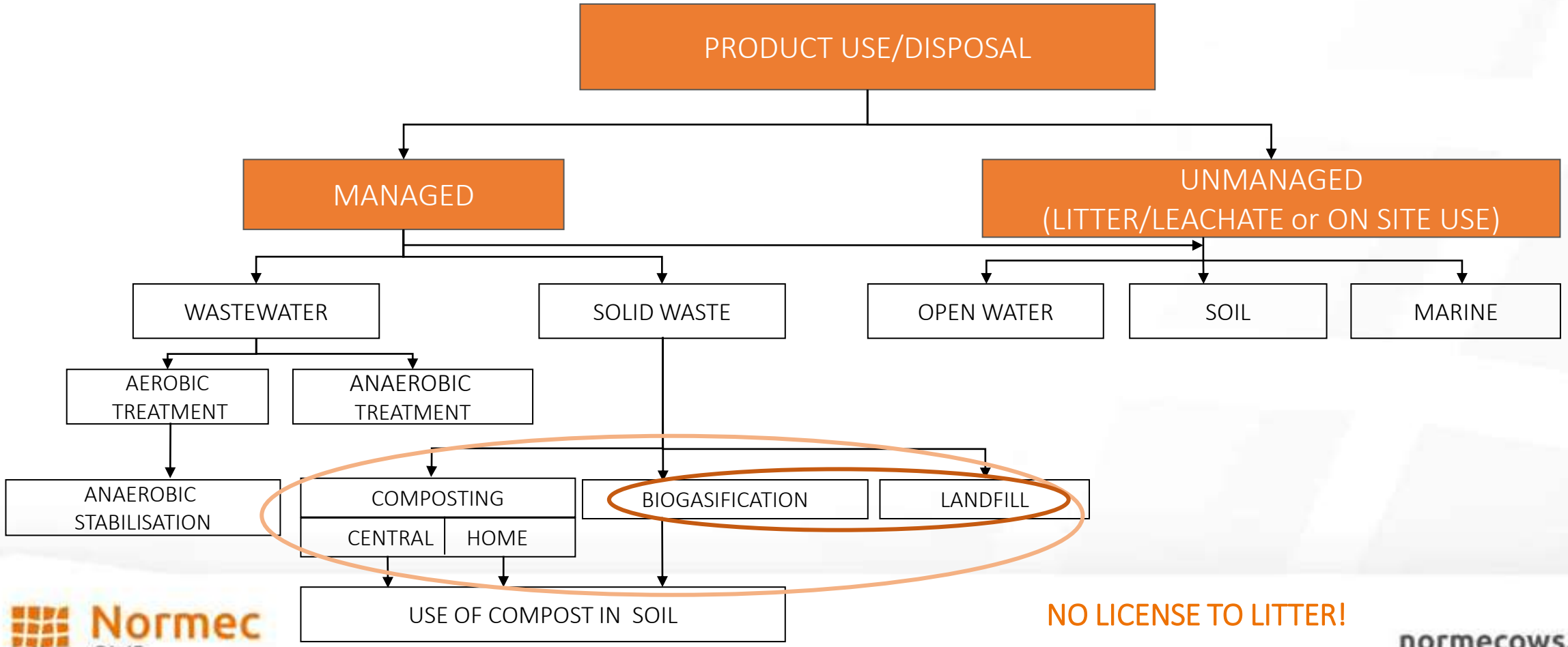
→ end-of-life

- Diverting biowaste from landfill to compost
- PPWR recognizes benefit of composting for some materials, when:
  - higher biowaste capture
  - lower contamination of compost by non-biodegradable plastics
- Incineration is not ideal
- Increase carbon level into compost
- Hard to recycle products (laminates, small formats, tea/coffee capsules…)






Biodegradation in controlled environments: anaerobic



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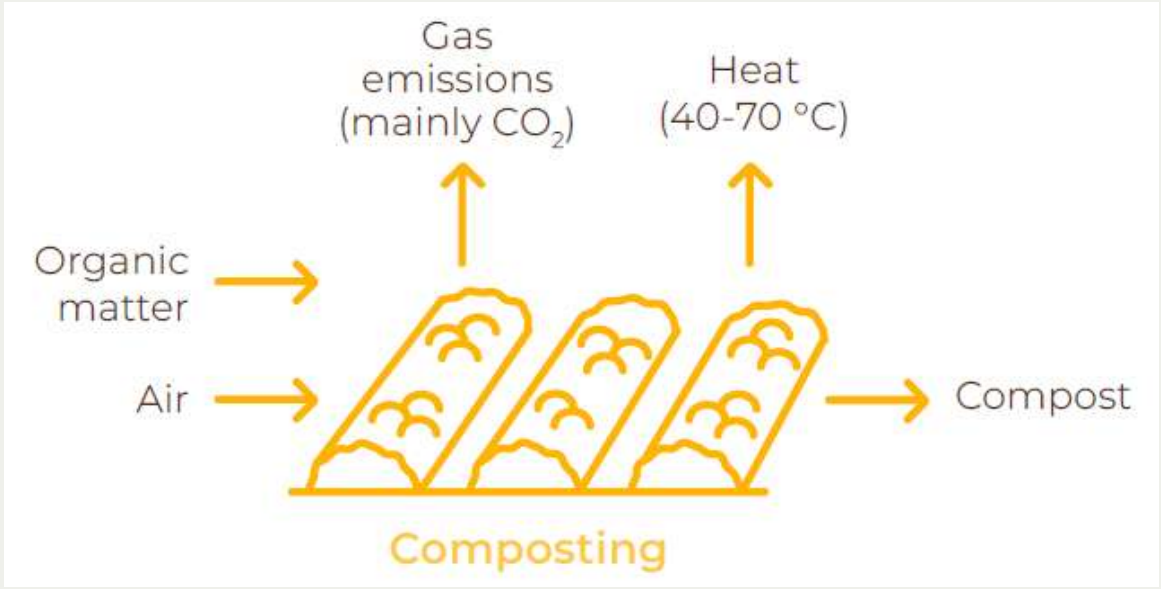
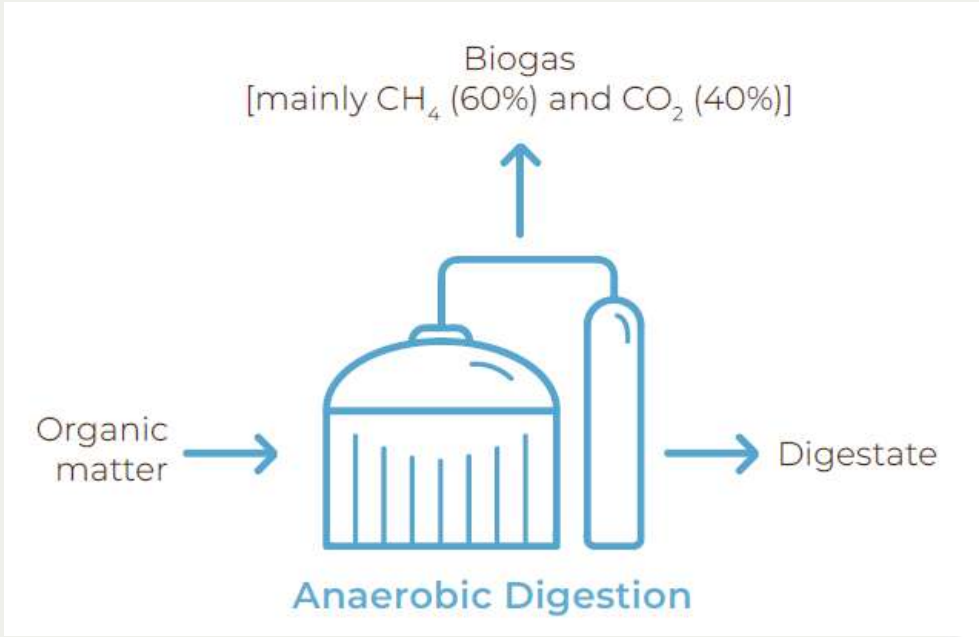
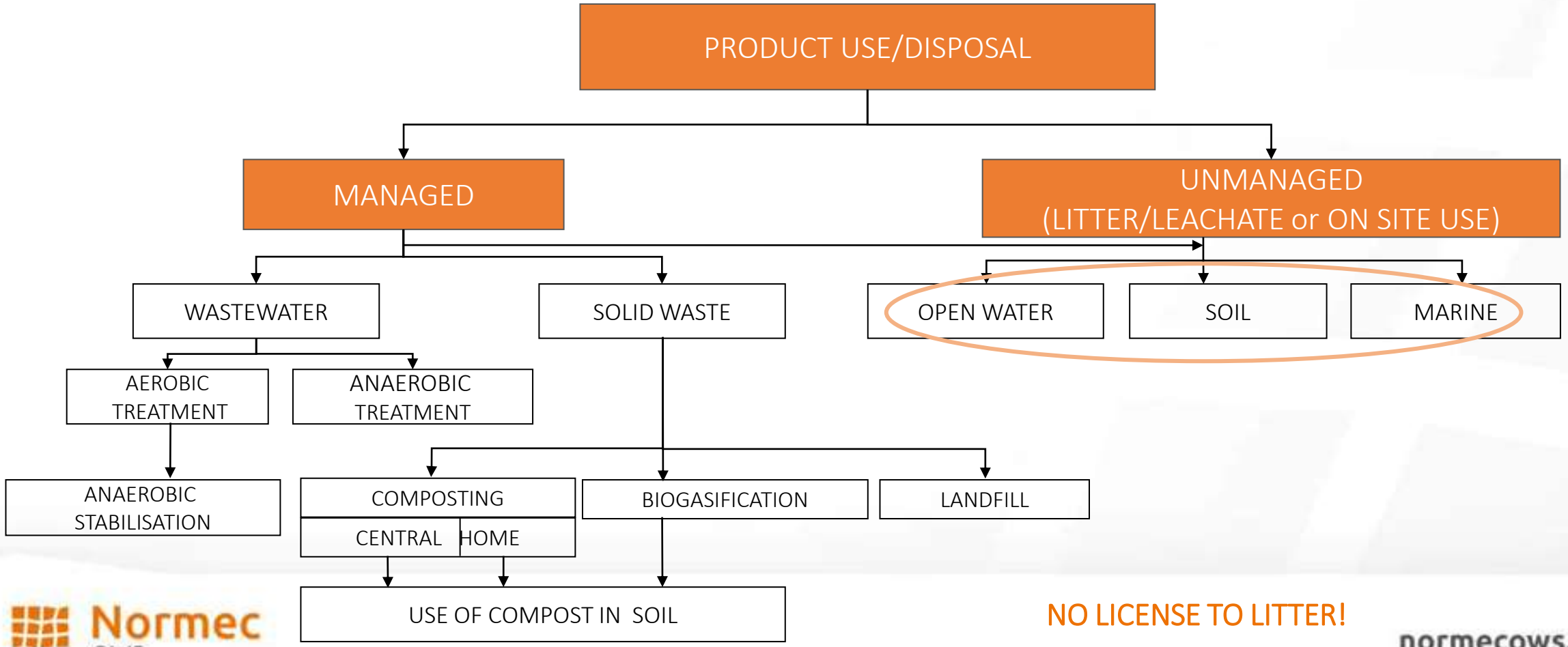
AEROBIC vs. ANAEROBIC DEGRADATION





Source drawings: closedlooppartners.com/wp-content/uploads/2024/03/3.19.24_CLP_ADCompostablePackagingWhitePaper_FINAL.pdf

Biodegradation in uncontrolled environments



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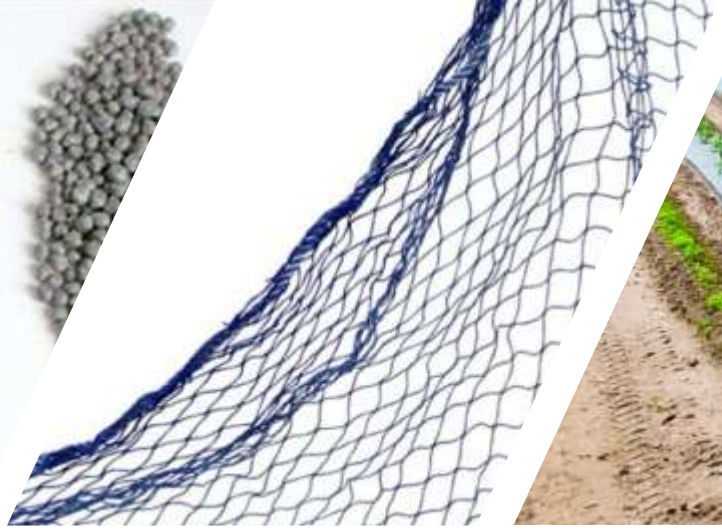

Opportunities for biodegradation into open space

Intentional

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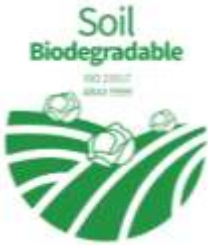
Opportunities for biodegradation into open space

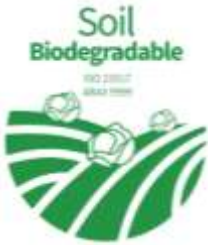
Unintentional

Biodegradation in open environments – Certification logos

	Soil			Fresh water	Marine water		
							
Schemes	OK biodegradable SOIL **TÜV AUSTRIA**	DIN GePrüft Biodegradable SOIL **DIN CERTCO**	Soil biodegradable **ABA**	OK biodegradable WATER **TÜV AUSTRIA**	OK biodegradable MARINE **TÜV AUSTRIA**	DIN GePrüft Biodegradable MARINE **DIN CERTCO**	DINplus Biodegradable MARINE **DIN CERTCO**
Standards	ISO 17556 ASTM D5988 ISO 11266	ISO 23517*: ISO 17556 EN 17033*: ISO 17556	ISO 23517*: ISO 17556	ISO 14851 ISO 14852	ASTM D6691	ISO 22403: ISO 18830, ISO 19679, ISO 22404, ASTM D6691, ISO 23977-1 (-2).	
Criteria	90% within 2 years.			90% within 56 days.	90% within 6 months.	90% within 24 months.	

standard specification (others: test methods)

Biodegradation in open environments – Certification logos

	Soil			Fresh water	Marine water		
							
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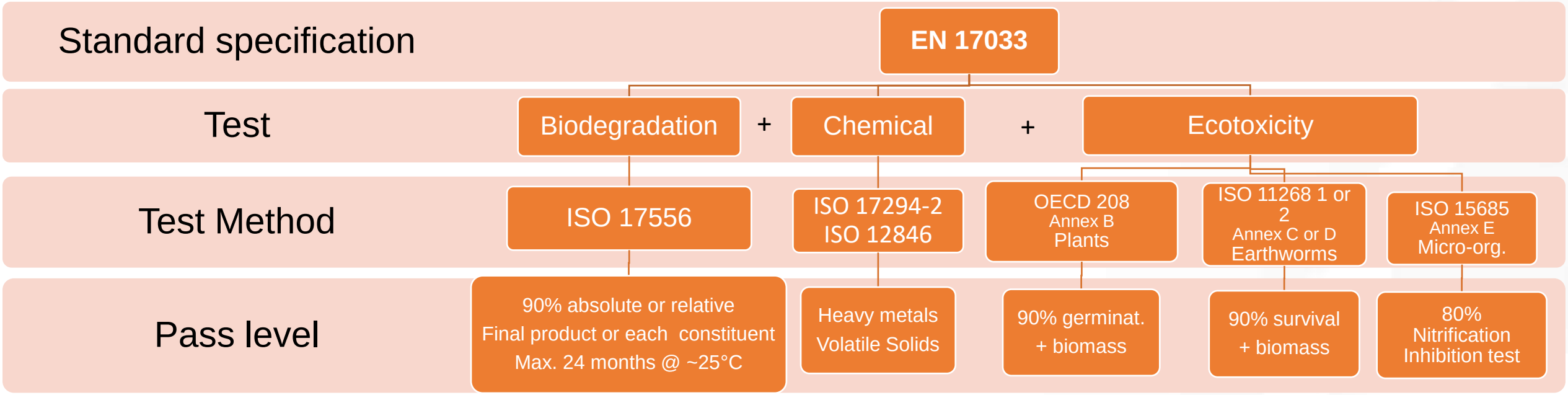
Criteria	90% within 2 years.			90% within 56 days.	90% within 6 months.	90% within 24 months.	

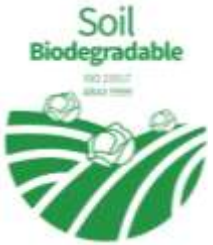
**standard specification (others: test methods)*

Biodegradation in soil

Mulch films



Biodegradation in open environments – Certification logos

	Soil			Fresh water	Marine water		
							
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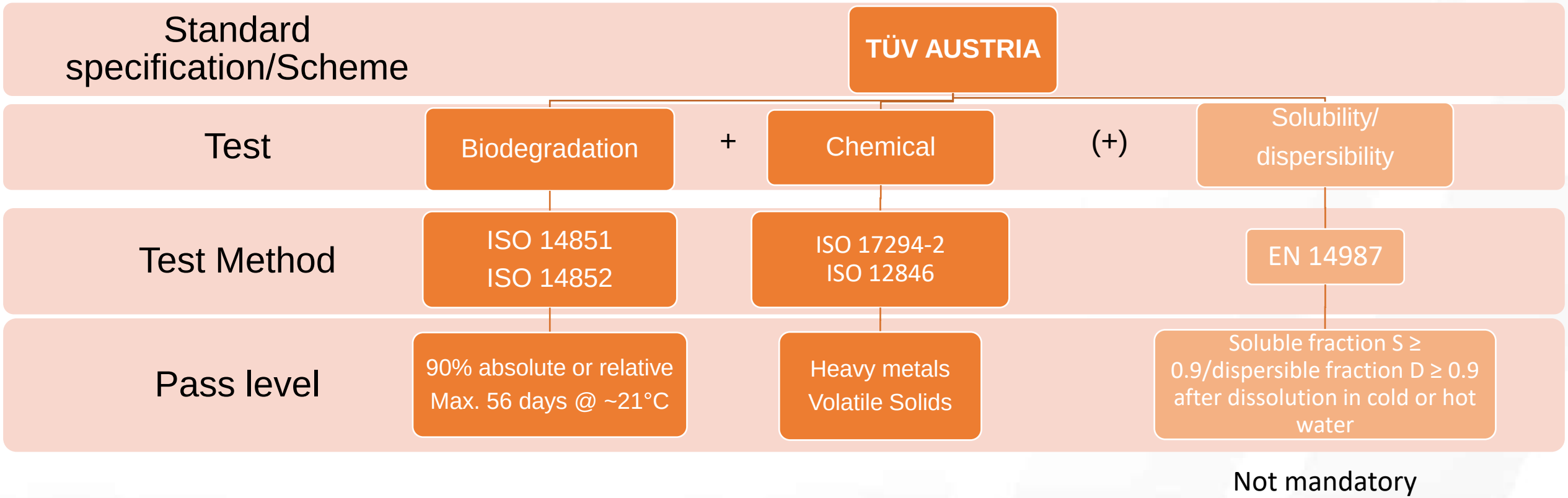
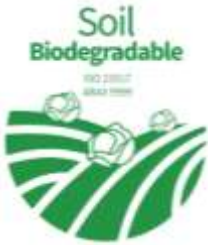
Criteria	90% within 2 years.			90% within 56 days.	90% within 6 months.	90% within 24 months.	

**standard specification (others: test methods)*

Biodegradation in fresh water



Biodegradation in open environments – Certification logos

	Soil			Fresh water	Marine water		
							
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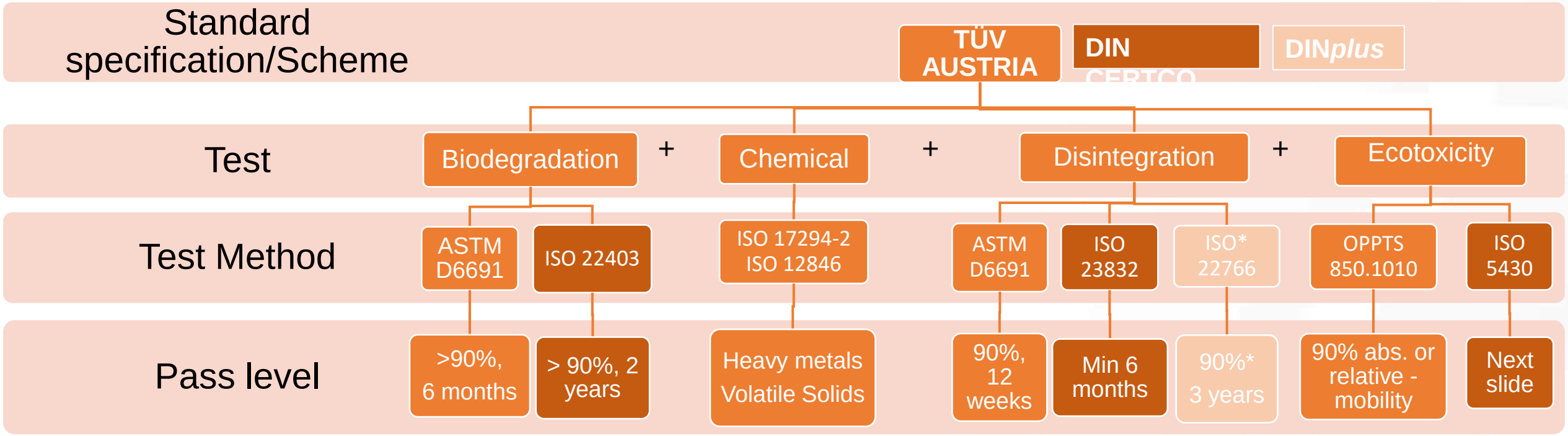
Criteria	90% within 2 years.			90% within 56 days.	90% within 6 months.	90% within 24 months.	

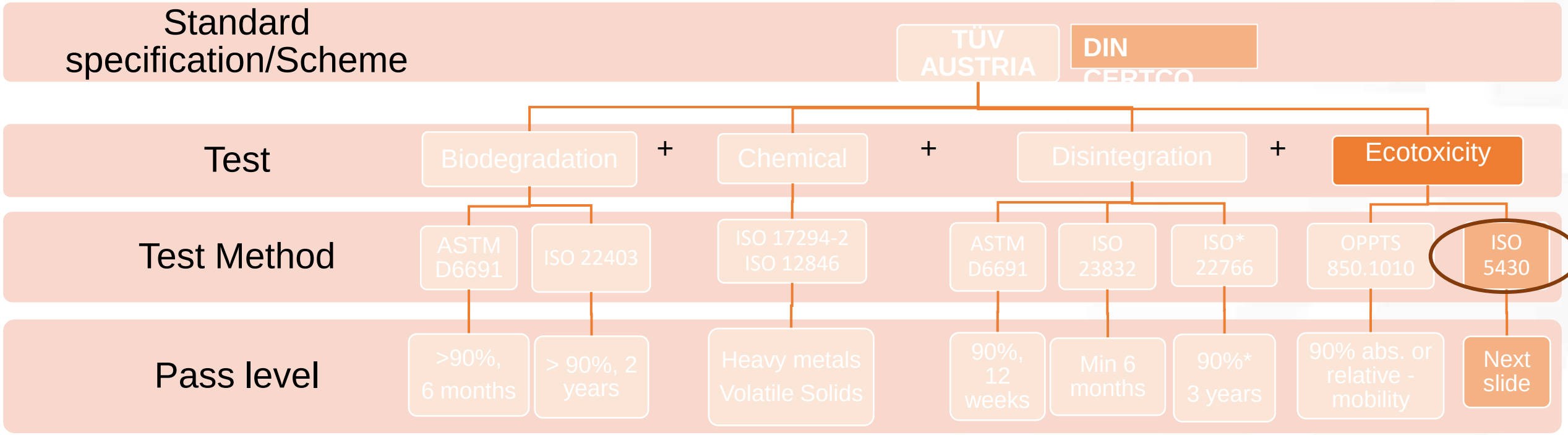
**standard specification (others: test methods)*

Biodegradation into marine environment



*for DIN*plus* certificate only: disintegration under real life conditions.

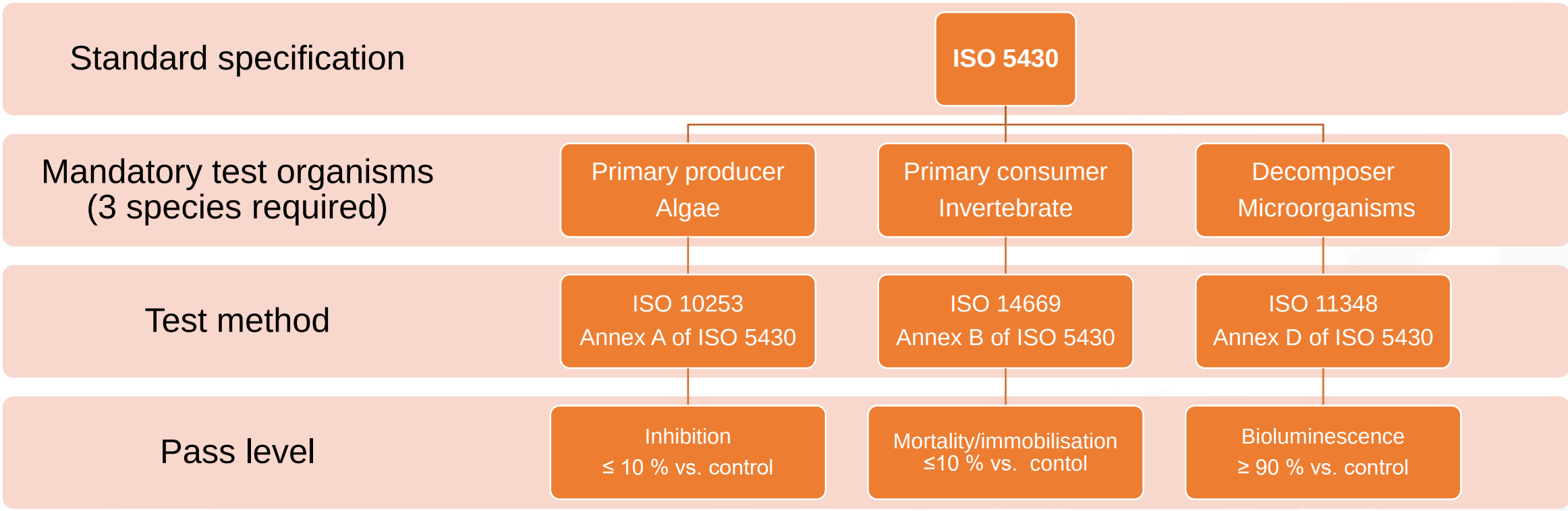
Biodegradation into marine environment



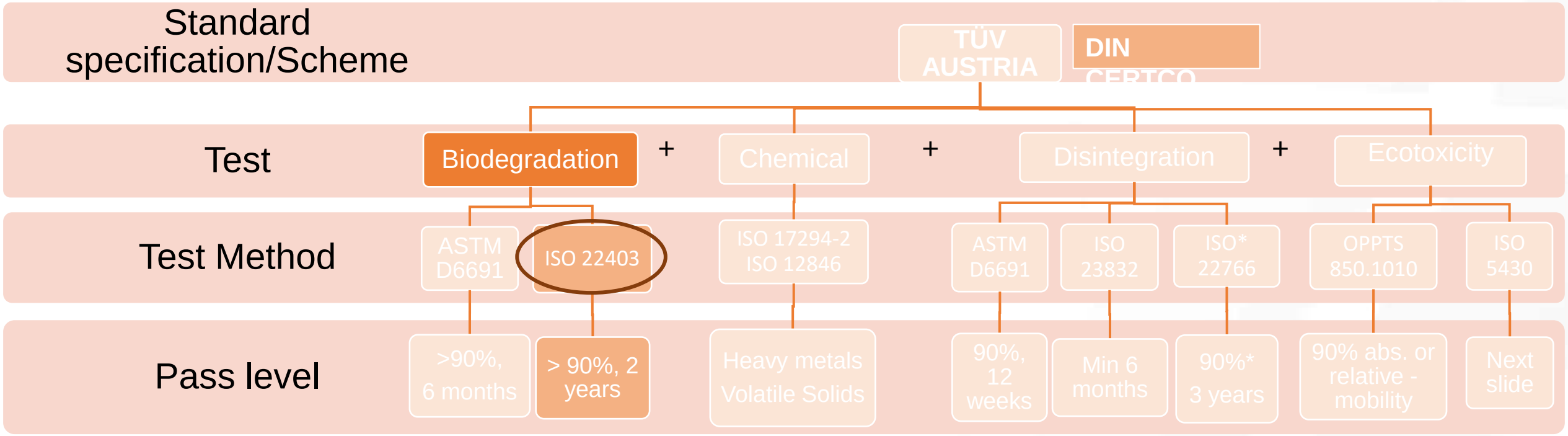
*for DIN*plus* certificate only: disintegration under real life conditions.

Eco-toxicity into marine enviroment

For certification with DIN CERTCO (DIN & DIN*plus*)



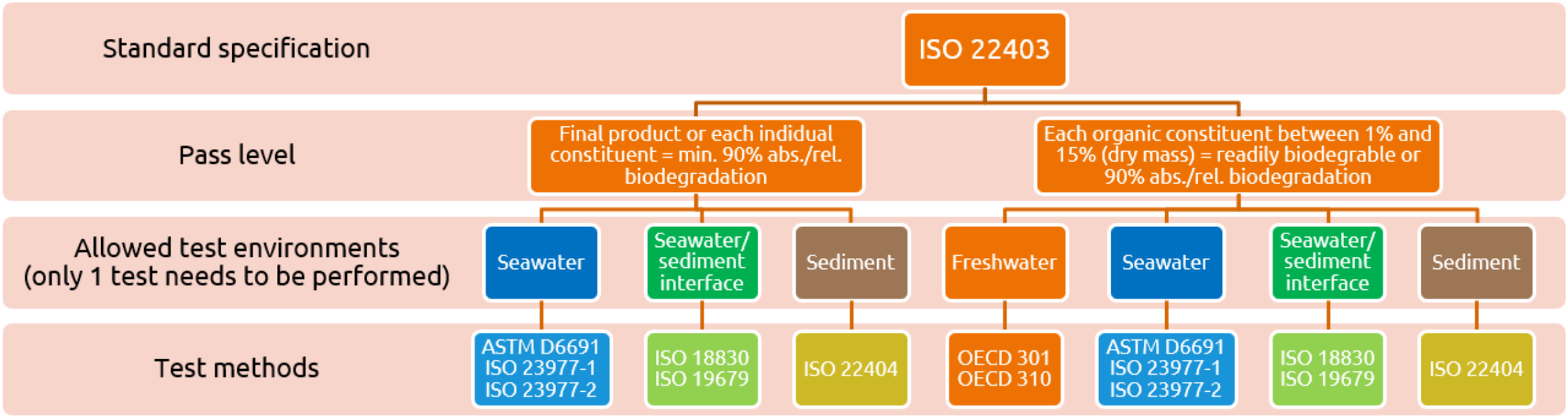
Biodegradation into marine environment



*for DIN*plus* certificate only: disintegration under real life conditions.

Biodegradation into marine environment

For certification with DIN CERTCO (DIN & DIN*plus*)



EU-projects

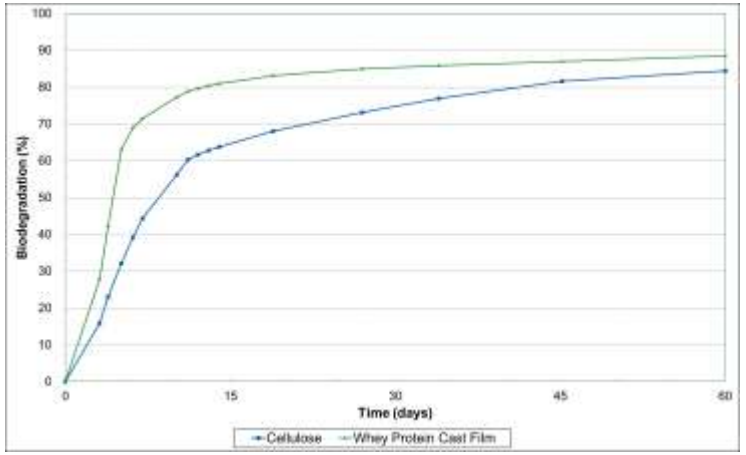
EU research

PRESERVE

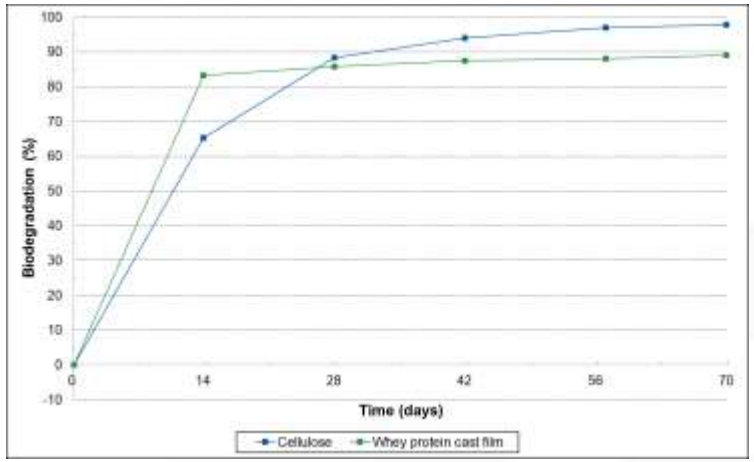
- **Ambition**: High performance sustainable bio-based packaging with tailored end of life
- **Whey protein coating**: improved oxygen barrier
- Biodegradable

Hochschule Albstadt-Sigmaringen
Albstadt-Sigmaringen University

Industrial composting (ISO 14855): **> 90% rel.**

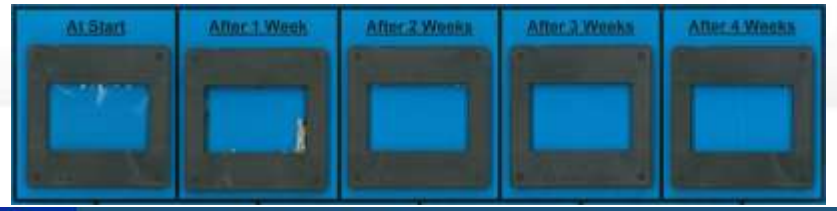


Marine (ASTM D6691; 30°C): **> 90% rel**



- Industrial composting (ISO 16929): double WPI coated PLA film (0.5 mm; coating 2 × 5 µm)

Complete disintegration



This project is funded by the Horizon 2020 Framework Programme of the European Union under Grant Agreement Number **952983**

Normec OWS

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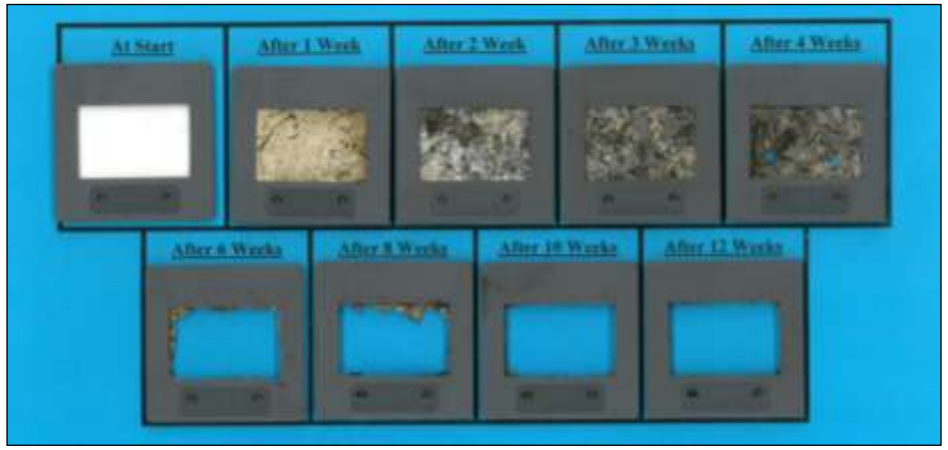
EU research

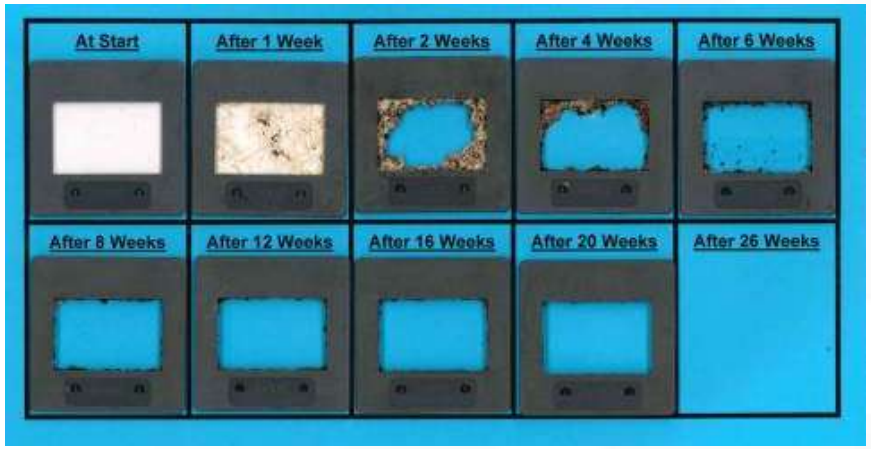
PRESERVE

- **PHA coated paperboard**: less water absorption
- Coated paperboard: thickness: 0.51 mm, grammage: 361 g/m²

Industrial compostable (ISO 16929; 12w)



Home compostable (OK Comp. HOME; 26w)



This project is funded by the Horizon 2020 Framework Programme of the European Union under Grant Agreement Number **952983**

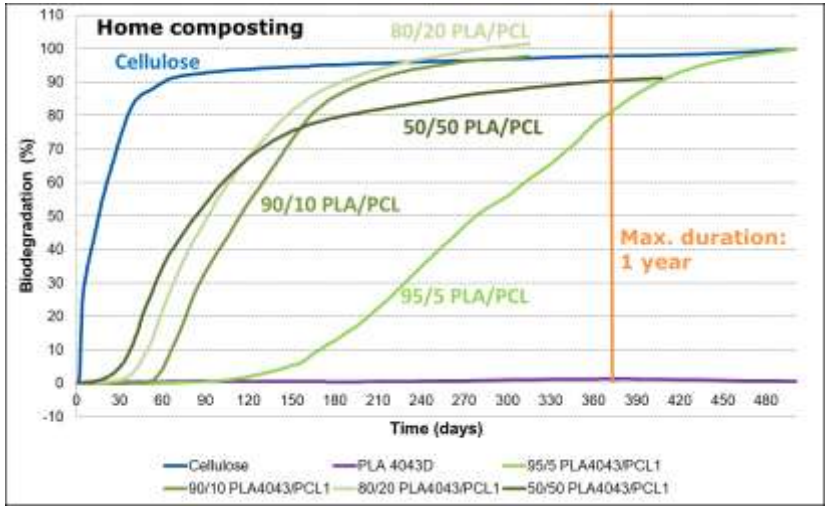
EU research

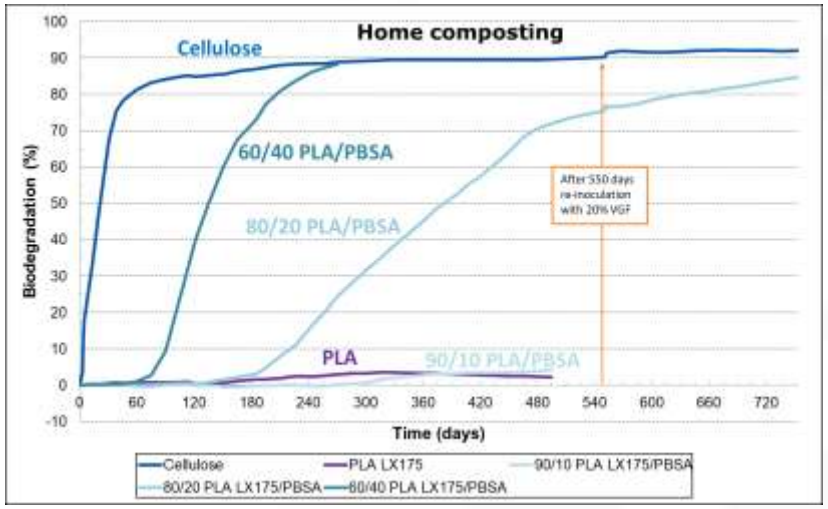
BIONTOP

- **Ambition:** Novel packaging films and textile: biobased – biodegradable at mild conditions
- Start material: PLA (bio-based, biodegradable, most affordable, high production capacity),

BUT needs thermal trigger for quick biodegradation

- Home compostable: blending with PCL or PBSA (type of PLA)





- Tuning the biodegradation!

This project has received funding from the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 837761.

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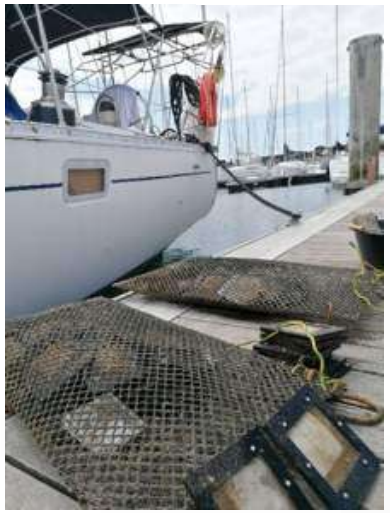
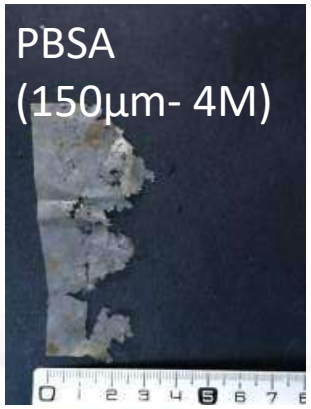
EU research

SEALIVE

- **Ambition**: bring advanced bio-based plastic solutions to the market
- Demonstrators:
  - Land: rigid and flexible packaging, **agricultural applications**
  - Sea: deep-frozen film, fish crates, oyster mesh bags, fishing net
- Important part on policy and standardization:
  - Marine toxicity tests for biodegradable polymers
  - 5 NWIP: standards (ISO – AD)
  - Marine disintegration: lab - field





		TÜV	ISO 23832	Real-life
Cellulose	6 Months	100%	0%	100%
Cotton		100%	0%	100%
PBS (50 µm)		0%	0%	100%
PBSA (50 µm)		100%	0%	100%
PBSA (150 µm)		100%	0%	100%
PHBV (50 µm)		100%	0%	100%
PLA LX175 (50 µm)		0%	0%	0%

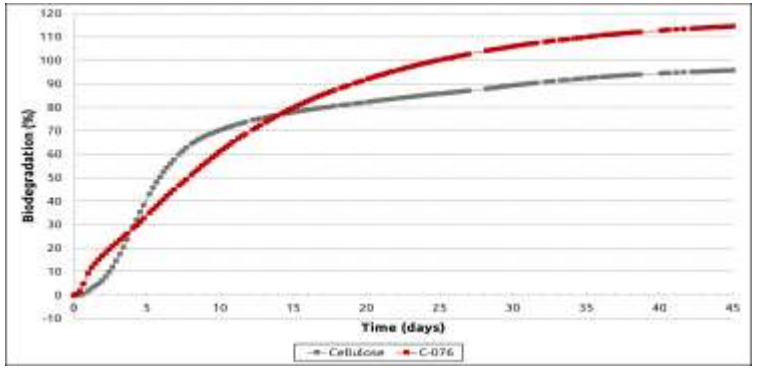
This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 862910 (SEALIVE). This output reflects the views of the authors and the Research Executive Agency (REA) is not responsible for any use that may be made of the information contained therein.

EU research

SEALIVE

- Mulch film - goal: industrial compostable & soil biodegradable
- Industrial composting

Biodegradation



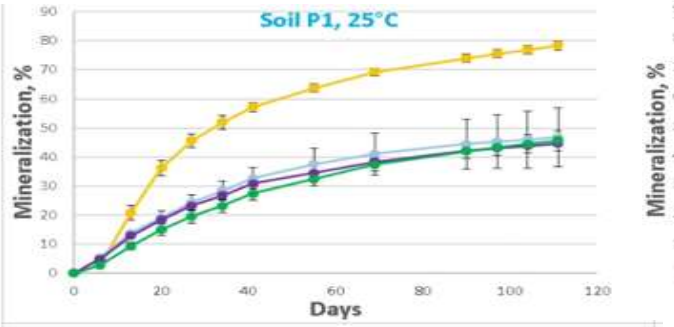
Disintegration

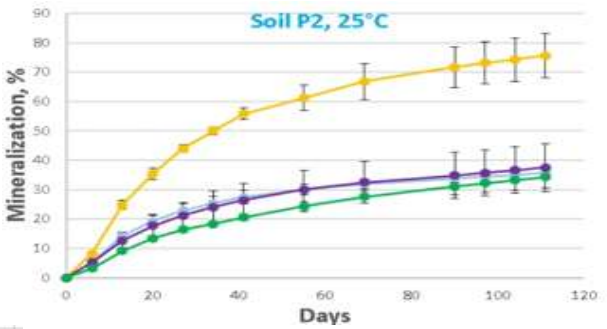
1 week

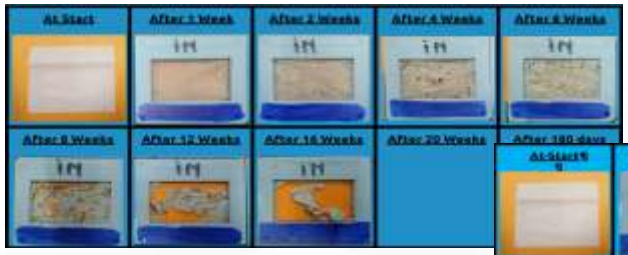
2 weeks

3 weeks

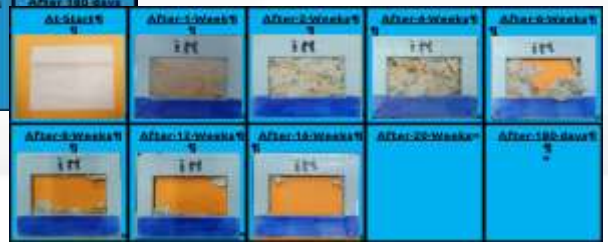
- Soil: biodegradation and disintegration (different sols, different temperature)







15°C



25°C

Normec OWS

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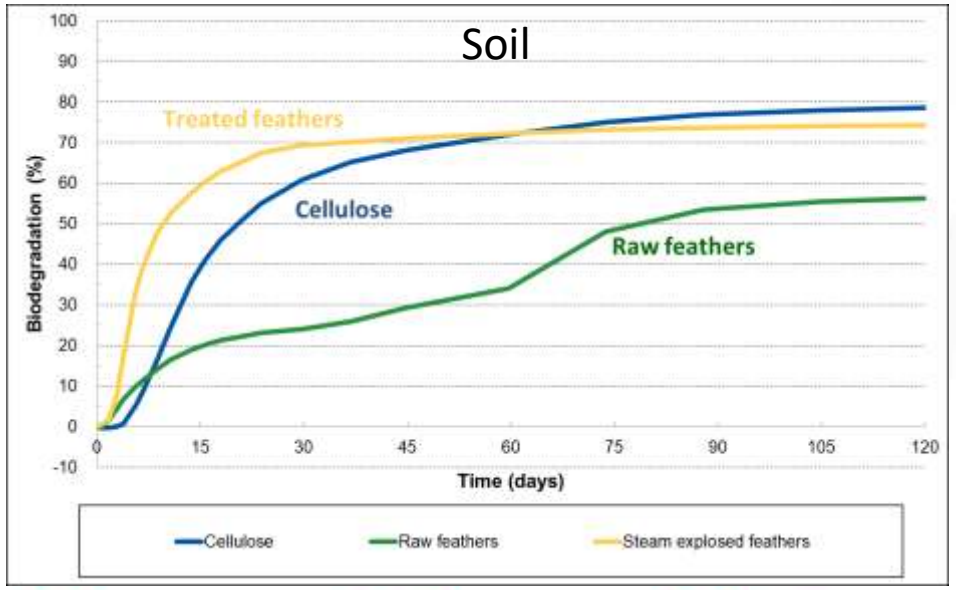
EU research

UNLOCK

- **Ambition**: releasing the potential of feathers to foster circularity in agriculture
- Keratin-based materials:
  - zero waste
  - controlled biodegradability
  - enriching soils with organic nitrogen



- Products

Mulch films

Hydroponic foams

Nonwoven geotextiles

Forest and seed trays

This project has received funding from the Bio-based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 101023306

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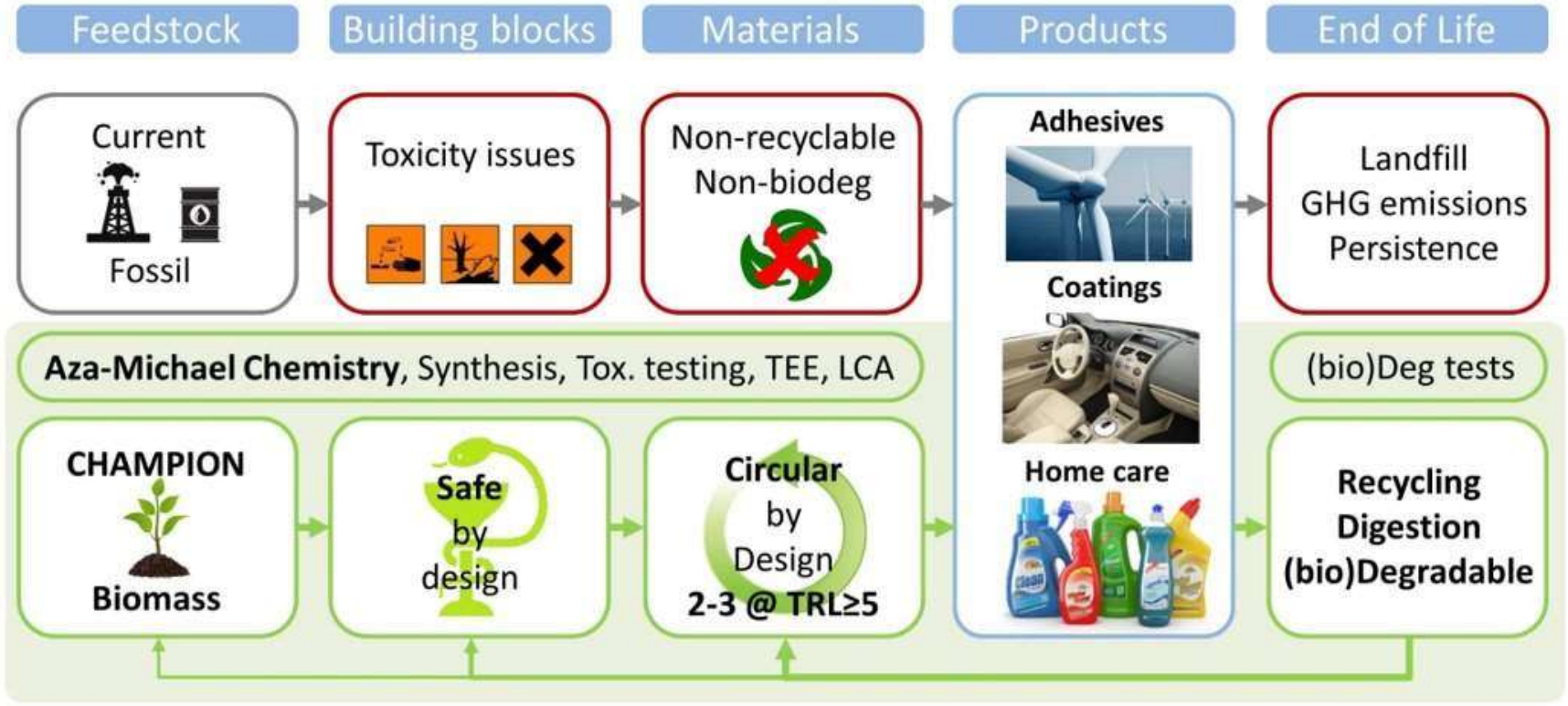
EU research

CHAMPION

- **Ambition**: Circular High-performance Aza-Michael Polymers as Innovative materials Originating from Nature



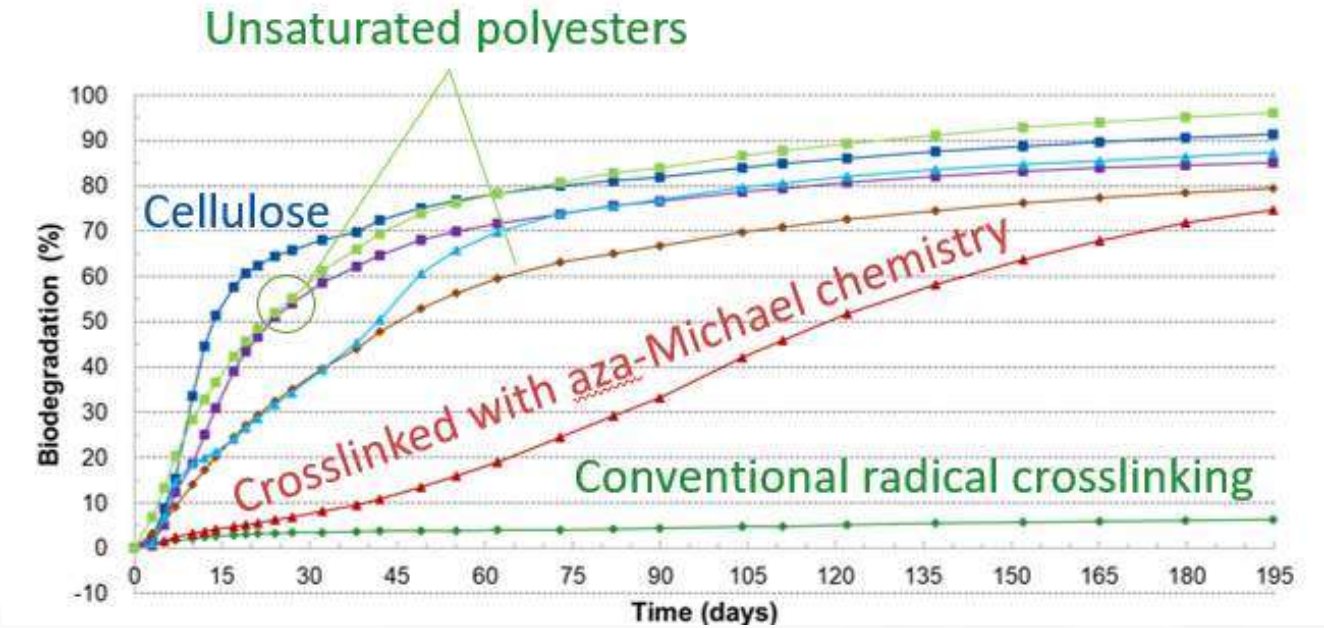
Champion project has received funding from the BioBased Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 887398

EU research

CHAMPION

- Conventional products: limited biodegradation
- Functionalisation with amines decreases biodegradability
- But amine crosslinking improves biodegradation over radical polymerisation crosslinking

- Accelarated soil biodegradation test (37°C)



Champion project has received funding from the BioBased Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 887398

EU research

MYFI

- **Ambition:** to provide the textile industry with a new nonwoven fabric made of mycelium fibres, with improved performances and reduced environmental impact in comparison with current commercially available fibres
- Environmental objectives:
  - Reduced use of chemicals and natural resources
  - Biobased: low carbon footprint
  - Circular: using residues form other value chains & closing loops
  - Option: biodegradable

This project has been funded under EU R&I programme Horizon 2020 with GA n° 101000719

Any further questions?

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