The Importance of

Standards, Test Methods, and Certifications

in the Biopolymer Industry

Contents

Introduction

According to the Ellen MacArthur Foundation (EMF), 78 million tons of single-use plastic packaging are produced every year - of which less than 2% is effectively recycled. Shockingly, 32% of this material is leaked into the environment as a result of inadequate waste collection and processing infrastructure. Given this reality, brands, manufacturers, and policymakers around the world are searching for ways to improve recycling rates and eliminate the damaging pollution caused by leakage. As a result, there has been a tremendous effort to develop packaging that can be recycled in various end-of-life environments.

Designing products and packaging with a focus on end-of-life has become an increasingly important consideration for brands and manufacturers. Consumers demand sustainability now more than ever, and brands must adapt and innovate accordingly to deliver more sustainable solutions to their customers. As a result, the need for certifications based on specification standards for these new and innovative materials has never been greater. In order to create a truly sustainable future, we must ensure end-of-life claims are based on science and accepted international standards.

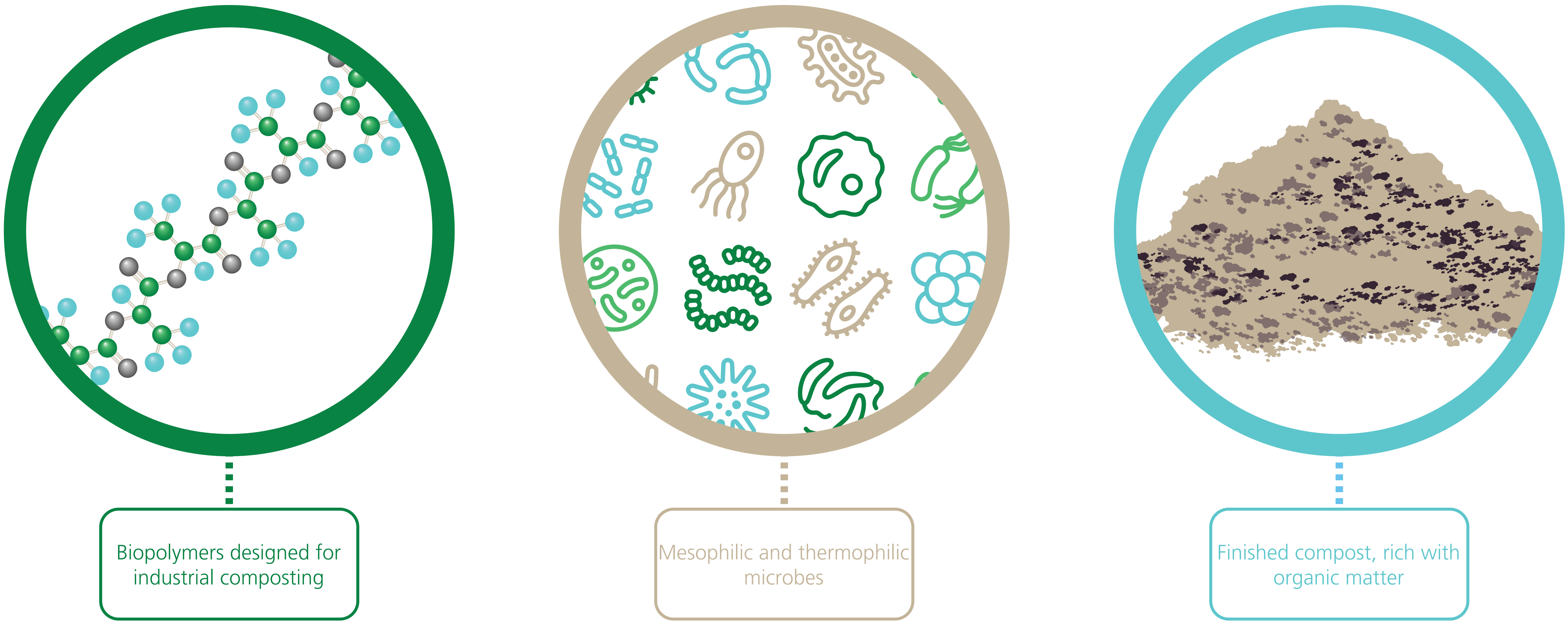
End-of-Life & Bioplastics

Given the realities of pollution caused by plastic packaging leakage into the environment, global brands and policymakers are searching for ways to improve recycling rates. As a result, there has been a tremendous effort to develop packaging that can be recycled in various end-of-life environments.

To combat pollution caused by plastic waste and climate change, it is crucial to focus on end-of-life. End-of-life refers to a product or material's final disposal environment where it will reside until it is broken down into the elements from which it came. Bioplastics offer many opportunities to reduce reliance on traditional plastics, reduce carbon footprint, and in some cases, be composted with other organic materials. However, to better understand bioplastics and their implications on different end-of-life environments, we must first explore the science and process behind biodegradation.

Why Compostable Plastics Biodegrade

Certified compostable plastics are engineered to contain chemical linkages in the polymer backbone that are susceptible to abiotic (hydrolytic, photolytic, or oxidative) or biotic (enzymatic) reactions, which reduce the polymer to smaller molecules (oligomers) or polymer fragments. Once the polymer chains have been broken, these residues are completely metabolized by a microbial consortium in a specified system (for example, industrial composting, anaerobic digester, agricultural soil, or wastewater) within a defined time as a food and energy source, releasing carbon dioxide and water, leaving cell biomass behind.

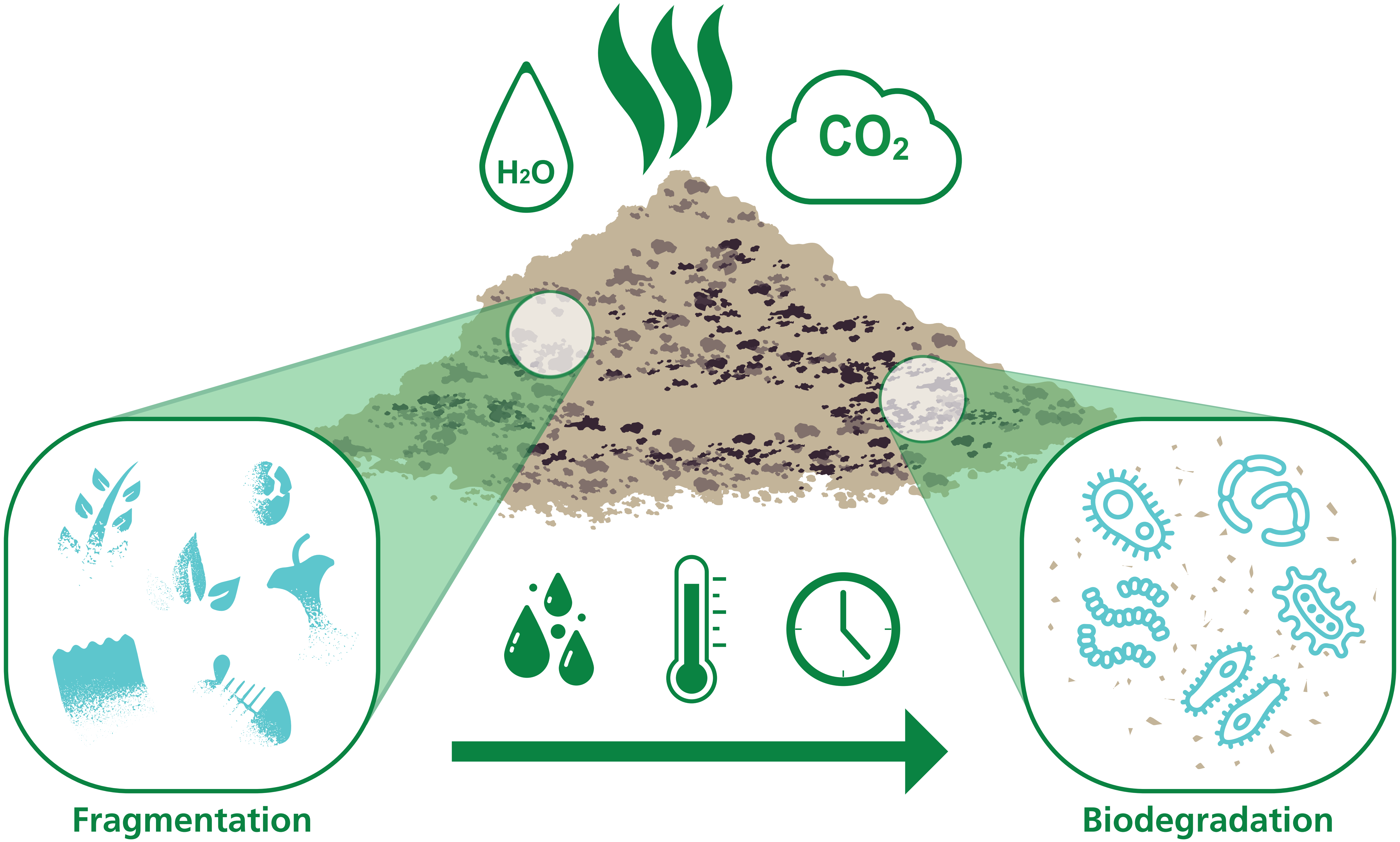


Composting in Context

The standards for compostability call for 90% conversion, via biodegradation, of the compostable packaging to carbon dioxide, water, and biomass via microbial assimilation in under 180 days.

Fragmentation/Disintegration
The first step in the biodegradation process is when organic matter is broken down into microscopic fragments.

Biodegradation
The complete microbial assimilation of the fragmented product as a food source by the soil microorganisms.



Compostability

Complete assimilation within 180 days in an industrial compost environment.

End-of-Life – Closing the Loop

In an effort to support sustainable material management that results in increased recycling rates, end-of-life must be considered alongside improvements to disposal infrastructure and product design. End-of-life concerns the ways in which materials are properly (or improperly) disposed of. Common end-of-life environments include: landfills, chemical, and mechanical recycling, industrial compost facilities, etc. As brands, manufacturers, and consumers pioneer sustainability, end-of-life is a crucial consideration, and the need for standard-based certifications is imperative.

When bioplastics are concerned, there are five end-of-life environments commonly referenced by manufacturers, policymakers, and brands alike. Despite claims from manufacturers, it is important to note that bioplastics are not suitable for certain end-of-life environments. These misleading claims cause confusion that results in contaminated recycling streams and pollution. Therefore, we must explore each of these end-of-life environments and their relationship with bioplastics.

When bioplastics are concerned, five end-of-life environments are regularly discussed:

- Industrial composting
- Home composting
- Soil biodegradation
- Marine biodegradable
- Landfill

Key Differences

in these end-of-life environments influence the types of materials suitable for sustainable disposal.

Marine and terrestrial environments are so varied that specification standards must be created to effectively evaluate any claims of marine or soil biodegradability. Key differences in these environments are varying microbial populations and activity as well as temperature, moisture, and levels of carbon and nitrogen, which impact biodegradation.

Differences in End-of-Life Environments

Today, there are commercially available technologies that claim "marine degradability" or "home compostable." However, it is challenging to evaluate these claims as they are based only on test method standards - not specification standards.

Industrially managed composting offers a highly controlled end-of-life environment where conditions and duration are stringently monitored to ensure proper and complete biodegradation.

Industrial Composting

Anything that was once living can be composted. Food scraps and waste should be sent to an industrial compost facility rather than a landfill. This includes food waste, organics, and materials that result from the storage, preparation, cooking, handling, selling, or serving of food. Industrial composting is an actively managed process where key factors are monitored to ensure effective and complete biodegradation. Composters monitor pH, carbon and nitrogen ratios, temperature, and moisture levels to maximize output efficiency and quality of the finished compost and to ensure compliance with industry regulations. When compostable food service packaging is concerned, industrially managed composting facilities regulate accepted materials based on adherence to specification standards such as ASTM D6400 and standards-based certifications such as the Biodegradable Products Institute (BPI) certification.

OK compost TÜV AUSTRIA INDUSTRIAL S0188

BPI COMPOSTABLE COMMERCIALLY COMPOSTABLE ONLY. FACILITIES MAY NOT EXIST IN YOUR AREA. CERT #0000000

ASTM INTERNATIONAL

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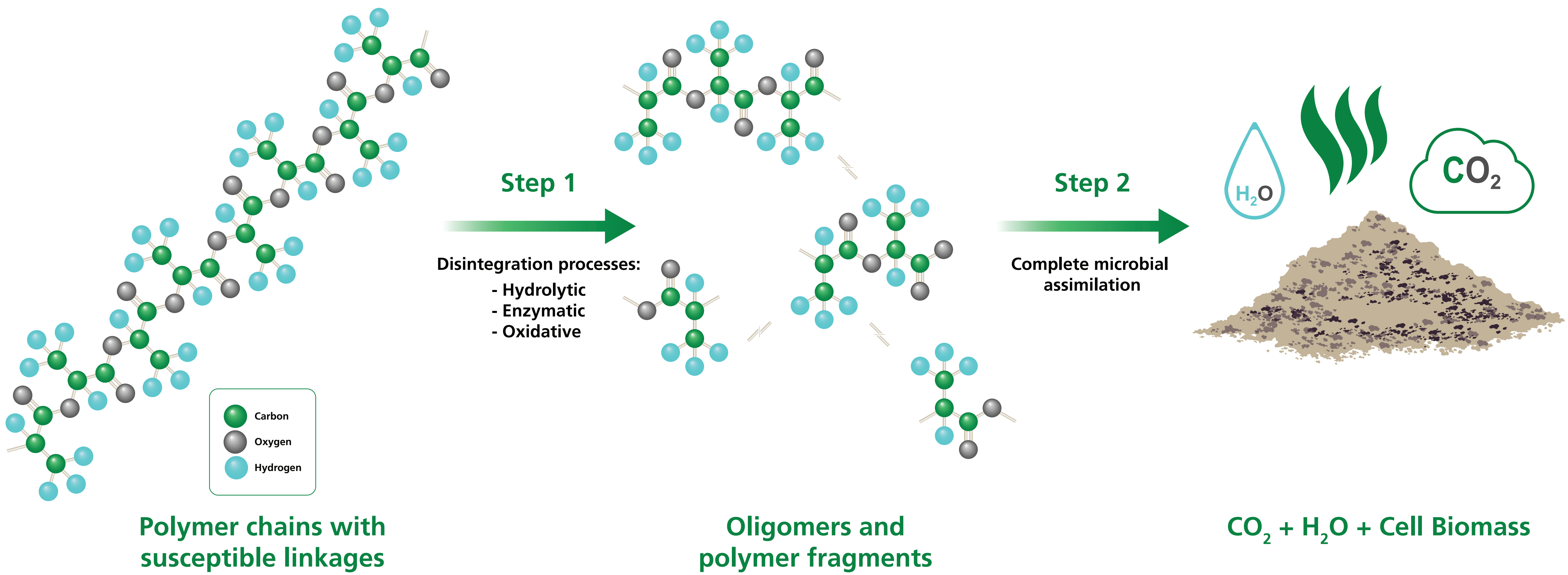
The Dirt On Composting...
Composting is the most effective and sustainable way to dispose of organic materials and certified compostable bioplastics. Composting repurposes the carbon contained within these materials, leaving nothing behind but heat, water, carbon dioxide, and biomass (compost). Compostable packaging also helps increase capture rates of food scraps and organics, resulting in higher recycling rates and increased feedstocks for composting while reducing food waste sent to landfills and the associated methane emissions.



Biopolymer Degradation in Composting

Biodegradation is the breakdown of organic matter by microorganisms in the environment. This process begins with fragmentation and is completed through microbial processes which repurpose the carbon. Unfortunately, there is no universal scientific definition for biodegradation that specifies the environment and duration of the process.

Composting is an actively managed process that defines both the environment and duration of the process (in an industrial composting facility, in less than 180 days, the same rate as natural materials - such as leaves and grass clippings). Certified compostable products are engineered not to disrupt the composting process. As microbes break down these and other organic materials, heat, water, carbon dioxide, and biomass are released, and no plastic is left behind.

Certified compostable plastics are engineered such that the polymer chains are susceptible to degradation through the hydrolytic, oxidative, or enzymatic disintegration processes. Once the polymer chains have been broken, microbes consume the fragmented residues as a food and energy source and release carbon dioxide, water, and cell biomass.

Home Composting

Home composting is a common way to dispose of organic materials such as grass clippings, leaves, and food scraps. However, due to the variation in home compost environments (temperature, moisture, pH, etc.) and how they are managed, it is challenging to develop an effective standard that compostable products can be certified to. While there is a home compostable certification in Europe, "TÜV OK Compost Home," it is based on standards with arbitrary timing and temperature profiles, falling short of defining the home compost environment. Currently, there isn't a certification in the United States, but there are active committee discussions along with field testing efforts that will help establish science-based standards that may eventually be used for home compostable product certifications.

Bioplastics at Home vs. Industrial Composting

Composting at home is an excellent way to reduce waste and return carbon to the soil. However, home composting lacks the consistency and regulation of industrial composting facilities. Specifically, pile size impacts biodegradation as heat dissipates quickly in small home compost piles. Temperatures reach only 35°C in home compost piles, whereas industrial compost piles can reach 55°C. Even when combined with food waste, compostable bioplastic packaging requires higher temperatures than can be achieved or sustained in a home compost setting. For large-scale food scrap and organics diversion and bioplastics, industrial composting is the most sustainable and efficient end-of-life environment.

Soil Biodegradation

Soil biodegradation is an increasingly prominent discussion when bioplastics are concerned. As modern agriculture seeks to integrate more sustainable materials into operations, it is important to consider what happens to these materials both during and after their useful life. This concerns specific applications such as agricultural mulch film, which is buried in soil and exposed to microbes - soil biodegradation is not meant to address plastics that end up in the environment as a result of pollution and litter. Instead, soil biodegradation addresses bioplastics that end up in a terrestrial soil environment as a result of their use or at the end of their useful life.

Bioplastics and Soil Biodegradation

Due to the longevity demands, where a product may need to perform for over two years, coupled with the variance of terrestrial environments, it is challenging to develop compostable plastics which will effectively biodegrade across all agricultural applications. In addition, current specification standards and test method standards evaluate biodegradation over a period of two years, so it is critical to till the compostable mulch film back into the soil for complete assimilation at the end of the growing season.

Marine Environments

Plastic pollution in marine environments is a major global concern. According to the Ellen MacArthur Foundation, 32% of all the world's single-use plastic packaging ends up in marine environments. This leakage results from inadequate waste management systems and infrastructure throughout much of the globe. As a result, many manufacturers are seeking "marine degradable" alternatives to conventional materials. Unfortunately, many products claim marine degradability referencing ASTM D6691, a test method standard where samples are tested at 30°C (consider the average temperature of the ocean is 4°C). This poses significant challenges when evaluating the biodegradation of plastics in ocean waters, as the rate of biodegradation is greatly influenced by temperature. Further, the test method standard states, *"caution shall be exercised when extrapolating the results obtained from this or any other controlled-environment test to disposal in the natural environment."* Today, there is no standard for evaluating claims of marine degradability - as such, any claim of marine degradability should be met with skepticism.

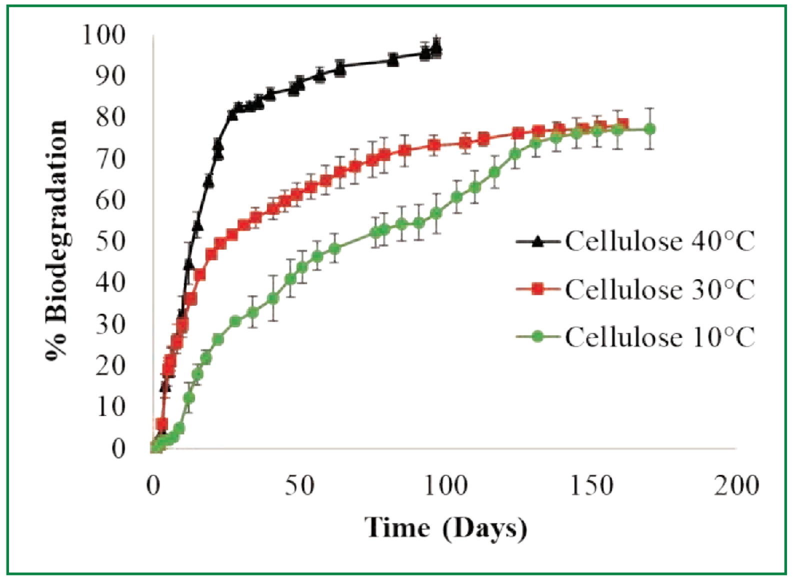
Marine Degradable?

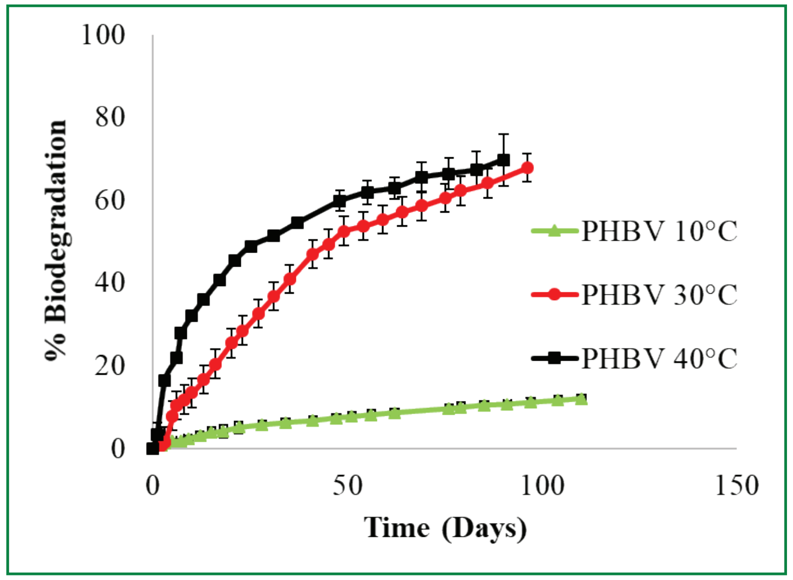
While the idea of a truly marine degradable material is promising when waste management is concerned, there are several challenges associated with regulating these materials. One key challenge is the variation in marine environments such as temperature, light permeation in waters near the surface and those at considerable depths, salinity, etc. Furthermore, in accordance with MARPOL, the world's oceans are not to be considered an end-of-life disposal environment for any type of waste. Therefore, any efforts to develop marine degradable materials should be ONLY to address the issues of leakage and pollution, not as an alternative to proper waste disposal.

Temperature Dependence and Marine Biodegradation

Temperature impacts the rate of biodegradation of any material in any environment.

Test-method standards for marine biodegradation, as previously discussed, are completed at temperatures of 25-35°C. However, 90% of the total volume of the world's oceans is found below the thermocline, where deep water temperatures are between 0-4°C. *The rate of biodegradation at these low temperatures is extremely slow. As such, materials under these conditions will persist in the ocean much longer than the observed results from testing at 30°C.* The graphs below show the relationship of biodegradation specific to various temperatures over time for Cellulose and PHBV (Poly(3-hydroxybutyrate-co-3-hydroxyvalerate).





Ref: Prof. Narayan, MSU, Webinar to the 2nd PHA Platform World Congress September 2, 2020

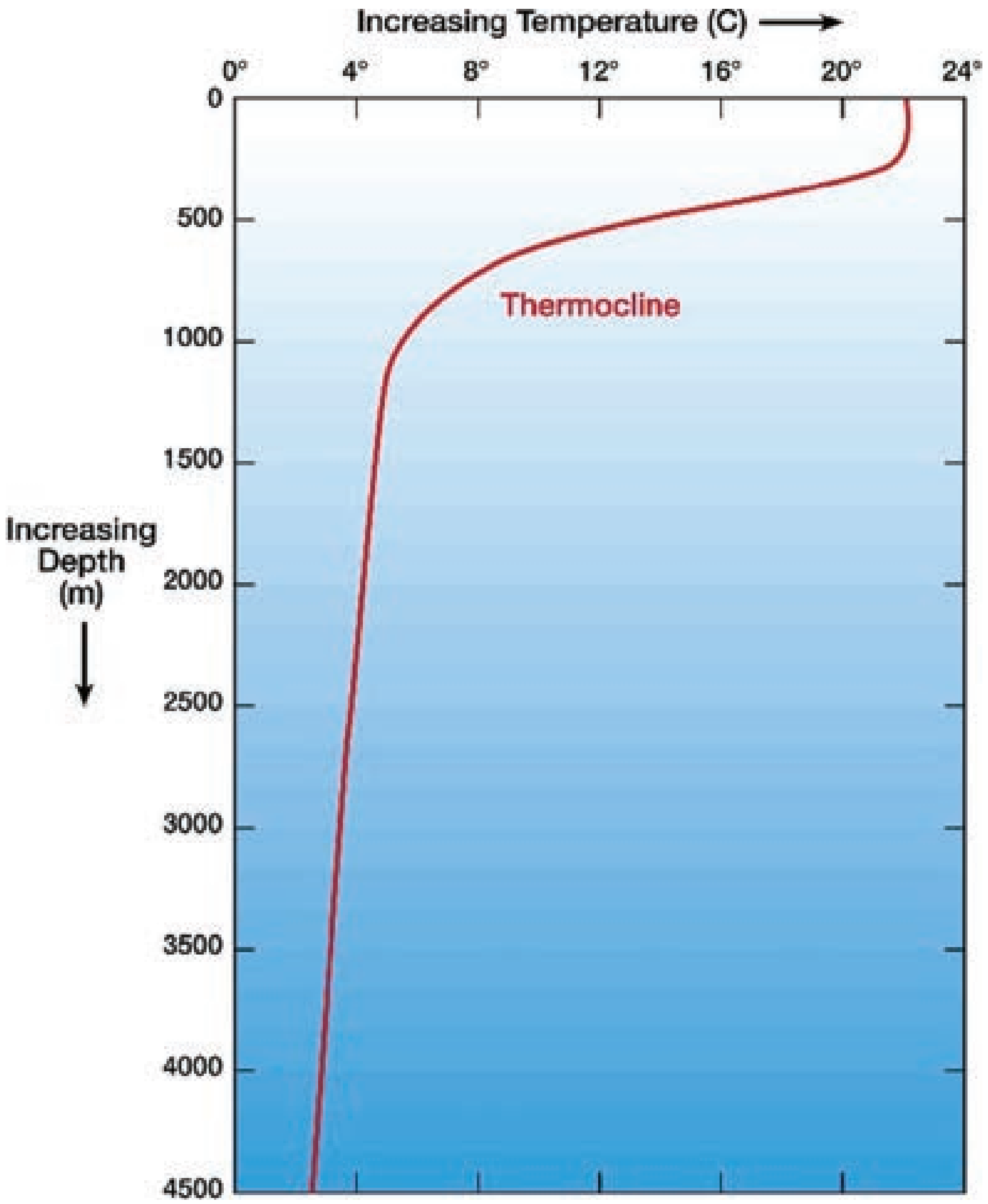
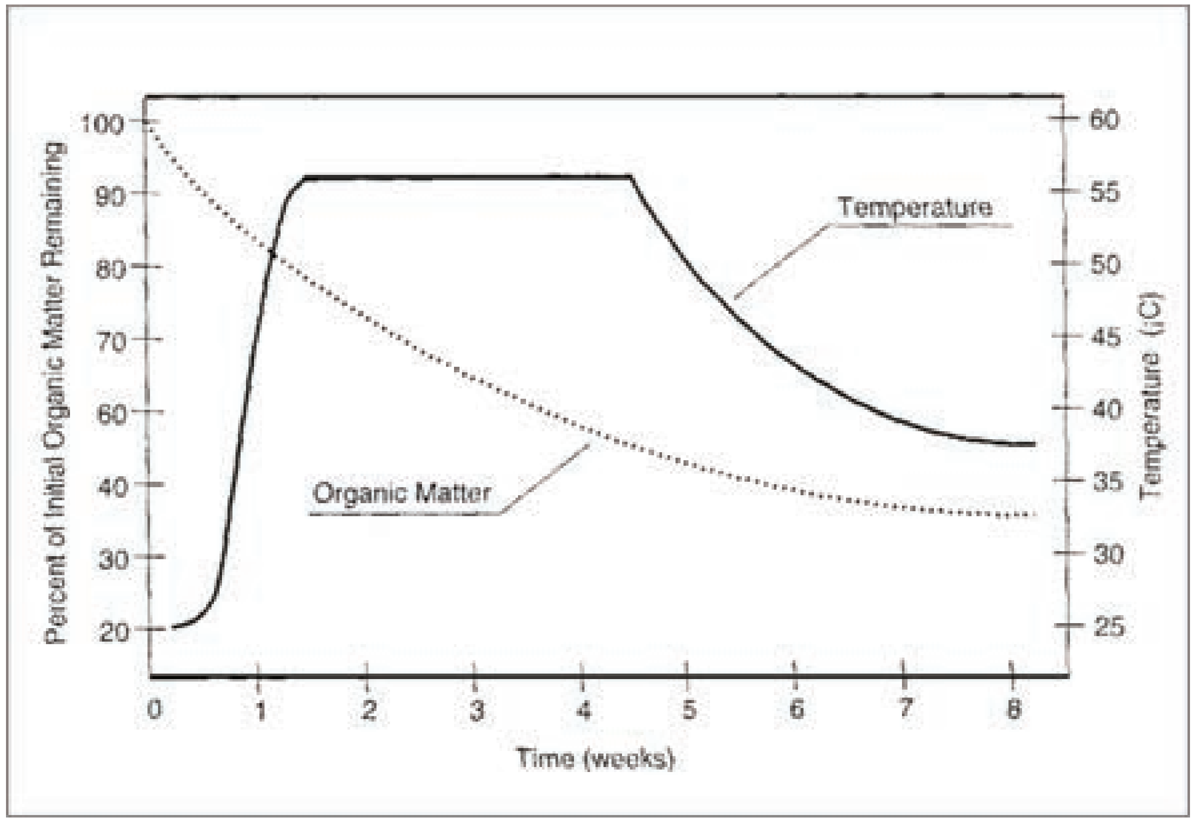


Image: Windows to the Universe

Temperature Dependence and Biodegradation in Compost

As it relates to the composting environment, there are multiple phases that facilitate biodegradation. Each phase is differentiated by the different microbial processes occurring as organic matter is metabolized by microorganisms. These processes result in the generation of heat. Compost heat is produced as a by-product of the microbial breakdown of organic material. The heat depends on the size of the pile, moisture content, and Carbon/Nitrogen ratio. This is referred to as microbial metabolism.

Throughout the composting process, as various microbial colonies are active, different materials are being consumed. Decomposition occurs most rapidly during the thermophilic stage (when temperatures reach 40-80°C), which lasts for weeks or months, depending on the size of the system. This stage is critical for destroying thermosensitive pathogens, larvae, and seeds. As temperatures drop to 20-45°C mesophilic microbes become active, leading to the end of the biodegradation cycle. At this time, the curing process is initiated, the compost is stabilized, and the process comes to an end.



Dr. Ramani Narayan, Michigan State University, www.msu.edu/~narayan

Landfills

In a landfill, waste is preserved for posterity! Nothing fully biodegrades in a landfill. When waste enters a landfill, it will be layered on top of other waste and then covered. Over time, as new waste material is added, the contents of a landfill compact. Because landfills are an anaerobic (without oxygen) environment, nothing can fully biodegrade as there are no microbes, heat, or oxygen to provide energy to the processes of biodegradation.

Food waste is the second largest category of municipal solid waste (MSW) sent to landfills in the United States, accounting for approximately 18% of the waste stream. That is over 35 million tons of food waste sent to landfills each year.

Organics and Bioplastics in Landfills?

When food waste, bioplastics, or other organic material enters a landfill, it will not biodegrade – these materials will be preserved for posterity within a landfill. Over time, organic material will decompose slightly and, in the process gives off gas methane (a harmful greenhouse gas, 23 times as potent as carbon dioxide). Because organic waste cannot fully biodegrade inside a landfill, the carbon and nutrients contained in the waste material are lost – buried for hundreds (if not thousands) of years. Composting and other organic recycling methods are the ideal way to dispose of compostable bioplastics and organic waste.

Standards, Test Methods, and Certifications

Standards and test methods play an important role in developing useful certifications for all types of materials. Test methods add structure to standards by detailing the ways in which the standard will be tested. The most intuitive certifications are based on pass/fail standards and require testing to be completed by 3rd party labs and facilities.

When bioplastics are concerned, there are several standard-based certifications, but there are other certifications based only on test methods which pose serious challenges to producers, regulators, and the environment.

Specification Standards

- Detailed set of conditions and provisions that a material, product, system, or service must meet
- Identify what test methods are appropriate to determine whether it meets the criteria of the standard
- Standards are pass/fail. Products/ materials either meet the requirements of the standard - or they do not

Test Method Standards

- Description of a procedure to determine a property or constituent of a material, a collection of materials, or a product
- The test method should include details about the test apparatus, test specimen, test procedure, and calculations of data obtained from the test

3rd Party Certifications

- Certifications refer to specification standards. A particular certification may reference one or more standards and will reference the testing of a product or material in accordance with the standard
- The criteria for certification is pass/fail as a product either meets the requirements of a standard - or does not

Standards, Test Methods, and Certifications Continued

	Test Method Standards	Standard Specifications	Certification	Updates
Industrial Composting	• ASTM D5338 • EN 14046 • ISO 14855	• ASTM D6400 • EN13432 • ISO 17088	BPI COMPOSTABLE; OK compost TÜV AUSTRIA INDUSTRIAL S0188; compostable	
Home Composting	TBD	AS 5810	HOME OK compost TÜV AUSTRIA HOME	BPI is looking to conduct field testing to collect data and provide input for an ASTM/ISO standard
Marine Biodegradable	ASTM D6691	TBD	MARINE OK bio-degradable TÜV AUSTRIA MARINE	ASTM has a working group looking to revise and re-ballot a standard specification for marine biodegradation (formerly ASTM D7081).
Soil Biodegradable	• ASTM D5988 • ISO 17556	EN 17033	SOIL OK bio-degradable TÜV AUSTRIA SOIL	

The chart above details common end-of-life disposal environments and the methods, standards, and certifications related to each. It is crucial to note that only industrial composting has certifications based on pass/fail standards. Likewise, home composting, marine biodegradability, and soil biodegradability can only be related to test methods. This means that these “certifications” only certify that a product or material has been tested in accordance with the relevant test method - it does not require a pass/fail of specific criteria, nor does it signify that true biodegradation takes place.

Dangers of Method-based Certifications

Test methods are extremely important as they define the process for the establishment of certification standards. Alarmingly, some manufacturers reference test methods when making claims of biodegradation in specific environments, such as ASTM 5511 (for anaerobic conditions) or ASTM 6691 (a test method used to measure aerobic plastic biodegradation in marine environments). Certification claims based on test methods are particularly dangerous as far as bioplastics are concerned, as these claims can cause confusion for even the most well-intended stakeholders.

There is much work to be done in order to effectively develop standards and certifications to evaluate the biodegradation of bioplastics in various end-of-life environments. In addition, brands, manufacturers, regulators, and scientists must consider the true impact of disposing of materials that are likely to enter the environment as pollution.

The New Standard in Sustainability

Sustainability is of paramount concern for brands and consumers alike. As we navigate the demands of the modern eco-conscious consumer, the end-of-life impact and disposal of products and packaging must be continually evaluated and regulated.

Pollution from mismanaged plastic waste is an issue at the forefront of many sustainability efforts. Micro-plastics transcend the boundaries of the elements and today are found in the deepest depths of the oceans, on remote mountains, and even in the air, we breathe. With the production of plastic packaging expected quadruple by 2050, the need for more sustainable material management combined with materials that can safely and completely biodegrade is clear.

There are ongoing efforts across the bioplastics and packaging industries to create better, more sustainable solutions to address the end-of-life challenges associated with single-use packaging. In the meantime, it is crucial to know the difference between standards, methods, and certifications and to be mindful of misleading marketing and product claims.

Suppose these yet undeveloped and unregulated materials are to be truly sustainable. In that case, it is critical that standards and certifications are developed specifically for these materials and their end-of-life disposal environments.

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Sustainable Biobased Materials

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