

# BALANCING BIODEGRADABILITY AND SUSTAINABILITY

## THE FUTURE OF POLYESTER IN TEXTILES, FABRICS AND FOOTWEAR

### WHITE PAPER

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## INTRODUCTION

Polyethylene Terephthalate (PET), a cornerstone of the textile industry, forms a significant portion of global clothing production. As an alternative to virgin polyester, recycling PET into r-PET filaments and yarns offers a sustainable solution. While studies like the one by the Swiss Federal Office for the Environment (2017) extol the virtues of recycled polyester, challenges persist, especially in recycling polyester blends used in textiles and footwear. This paper explores these challenges, highlighting the role of biodegradable additives and showcasing the advantages of recycled polyester.

However, recycling has its limitations. Every recycling step changes the properties of the new recycled product, the so-called 'downcycling'. Another problem is that Polyester is used in blends or mechanically combined with other materials, e.g., outer soles of shoes. This makes a second recycling circle much more difficult or even impossible and the second life has ended-up and the impact into the environment is happening later and the problem seems to be postponed but not solved.

We aim to illuminate a few more technical possibilities to address this issue and start processes which will make it possible to reduce the impact of used plastic materials into the environment, particularly into the rivers, lakes, and oceans.



# RECYCLING METHODOLOGIES AND CHALLENGES

Mechanical and chemical recycling are the two primary approaches for managing polyester waste. While mechanical recycling preserves the polymer's molecular structure, chemical recycling breaks it down at the molecular level. Both methods face challenges—mechanical recycling may lead to 'downcycling,' diminishing material quality with each cycle, and chemical recycling demands significant energy. Additionally, recycling blended fabrics common in footwear poses challenges due to material separation difficulties.

**Mechanical recycling** preserves the molecular structure. It mechanically crushes the plastic and remelts it into granulate. This granulate is then used to make new plastic products, e.g., Polyester filaments or fibers (r-PET).

**Chemical recycling** breaks the plastic down at a molecular level and eventually re-polymerized. However, this method requires high technology and significant energy consumption.

**Recycling by re-using** of clothing has a limited importance. Examples are making of bags by cutting and sewing together used home textiles, like beddings or curtains.

**Recycling by incineration** and other “waste-to-energy” technologies may be alternatives but pose unwanted dangers to the environment.

## Pros of Using Recycled Polyester

**Energy Savings:** The production of recycled polyester demands 59 percent less energy compared to virgin polyester.

**CO2 Emission Reduction:** Recycling PET reduces CO2 emissions by 32 percent compared to regular polyester.

**Resource Conservation:** Utilizing recycled polyester reduces the demand for new raw materials, conserving natural resources.

**Quality Parity:** Recycled polyester matches the quality of virgin polyester, offering a sustainable alternative without compromising performance.

**Circularity in Textiles and Footwear:** Recycled polyester contributes to a circular economy, offering a second life to materials in textiles and footwear.

# BIODEGRADABILITY OF PET AND OTHER POLYMERS

## Definition 'Biodegradable Polymers'

(IUPAC): biodegradable polymers are defined as "polymers, susceptible to degradation by biological activity, with the degradation accompanied by a lowering of its mass."

CEN/TR 15351:2006 requires a biodegradable material to be mineralized into carbon dioxide, water, and biomass during biodegradation.

## Biodegradability of PET: Pros and Cons of Additives

Biodegradable additives in PET offer a promising solution to plastic waste. Examining the advantages and disadvantages is crucial.

### Pros:

**Enhanced Biodegradation:** Additives accelerate PET breakdown, reducing its environmental persistence.

**Microbial Efficiency:** These additives facilitate microbial digestion, transforming PET into benign substances.

### Cons:

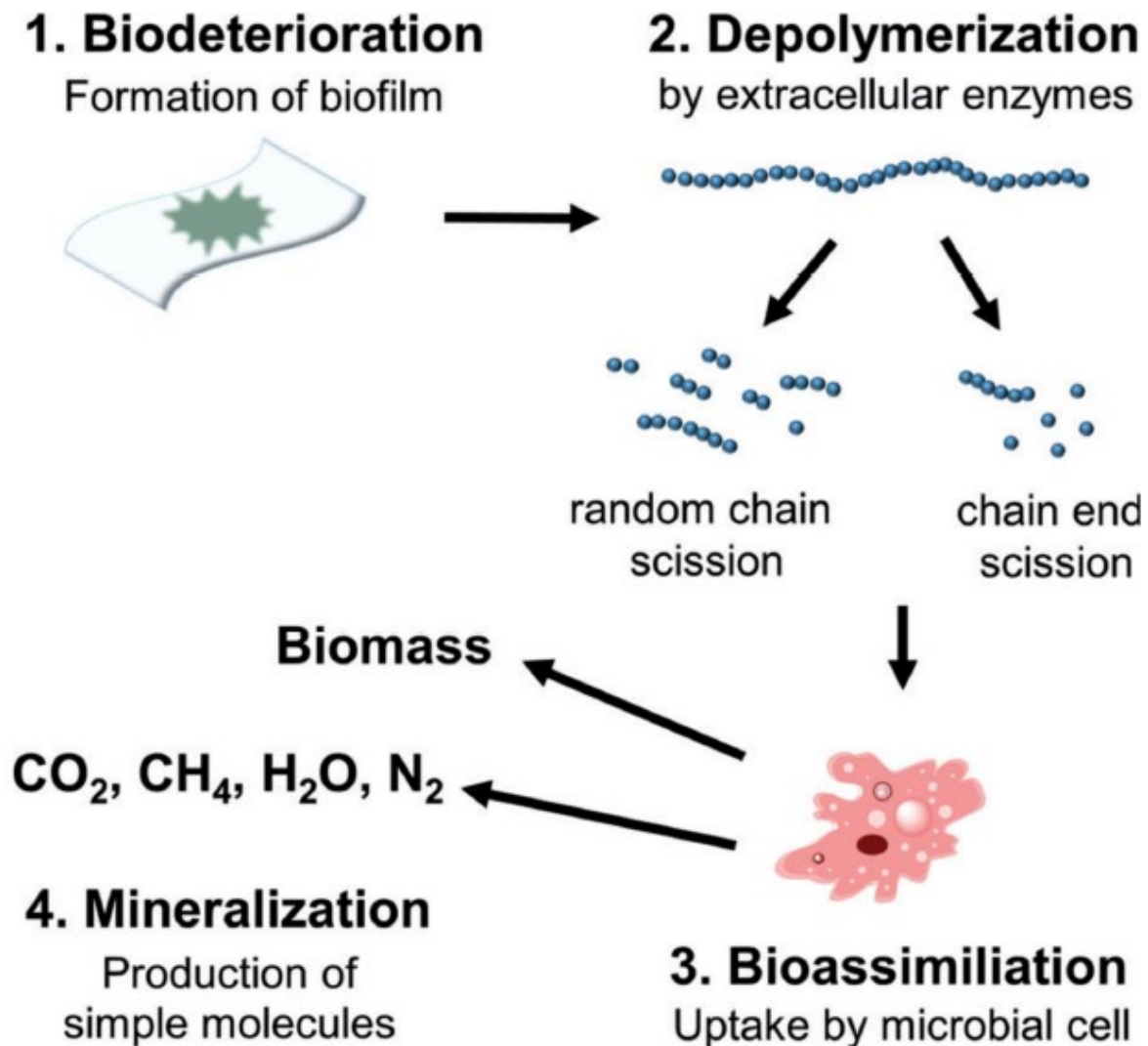
**Variable Efficacy:** Biodegradable additives' performance varies based on environmental conditions and polymer type.

**Ecological Impact:** Concerns exist about the breakdown products affecting soil and water quality.

**Economic Feasibility:** Incorporating additives can be costly, impacting product marketability.

**Lifecycle Trade-offs:** While aiding in biodegradation, additives might affect recycling or product durability, potentially increasing consumption, and waste.

## How Microbial Degradation works



Microbes that consume plastic have been studied since the early 90's a list of the microbial consortium that consumes plastic can be found in various articles and white papers. Some have been listed in this overview of additives that enhance biodegradation based on enzymatic action. Nuclear waste management conducted a series of tests that were for aerobic (with the presence of free oxygen) in 2012 for Styrene resin, they concluded that styrene resin could be broken down by microbial enzymes. Various bacteria families have been shown to breakdown polyethylene, polypropylene, and polyvinyl chloride. Popular science released an article that shows many different polymer types can be consumed by microorganisms in various environments. Simply put microbes exist in the environment and breakdown plastic.

Additives that are used to make plastic breakdown by enzymatic action interacting with the enhancers placed in the additives are different in formulation. Not all additives that work in breaking down plastic as an enhancer with enzymes are the same and they all perform differently. Some break down faster in other environments and may not break down different polymers the same or a mixture of polymers the same.

That is why testing is crucial in vetting technologies. The current examples of how plastic is broken down by enzyme enhancing additives are spoken specifically to one additive only, it does not apply to every technology or claimed technology on the market. While they may have some various catalysts, they do not work the same as each technology is different and performs differently.

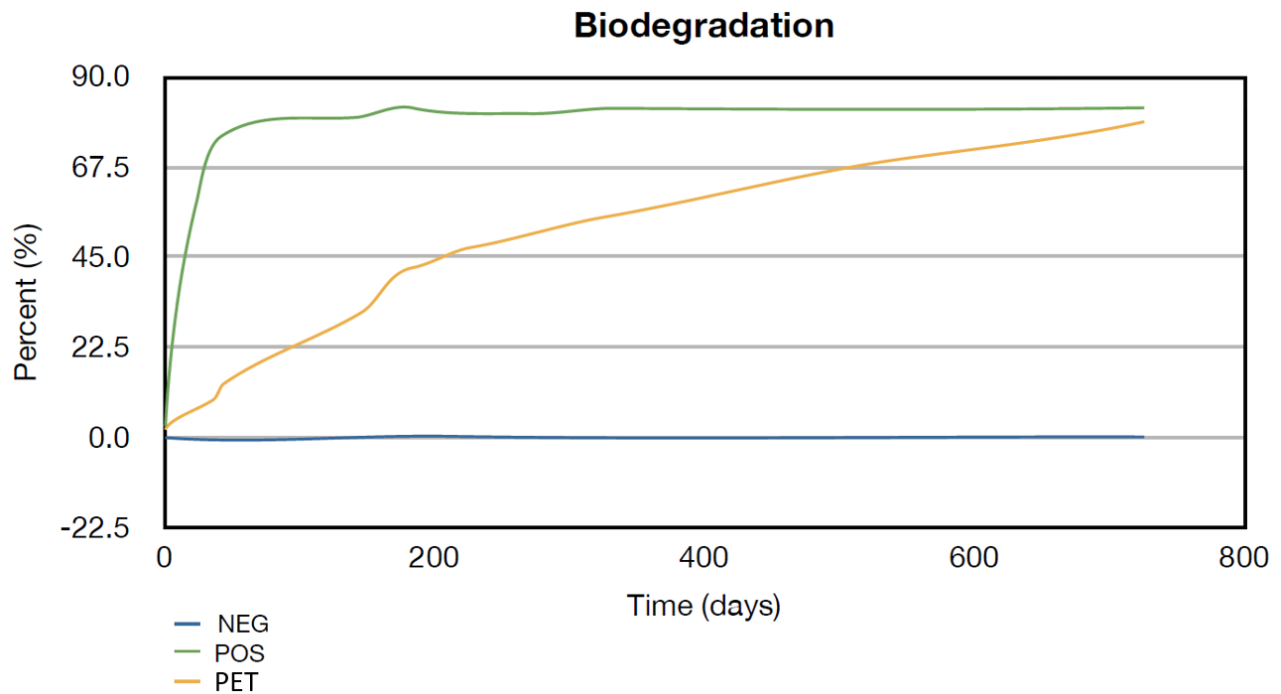
Polyethylene Terephthalate (PET) is broken down by enzymatic degradation by hydrolysis in a twostep process: Enzymes bind to the substrate then catalyze a hydrolytic cleavage. Polymers are then degraded into lower weight oligomers, dimers and monomers converting to CH<sub>4</sub>, CO<sub>2</sub> and H<sub>2</sub>O. All these functions are greatly enhanced by enzymatic additives that work as a catalyst.

### Testing Methods

Test Method	Environment	Criteria
ASTM D7475	Landfill Accelerated - Three Different Temperatures	Anaerobic and Aerobic
ASTM D6691	Marine - Floating	Aerobic - Under 1.027 Density (PP,PS)
ASM D5526	Landfill Accelerated - Varying Temperatures	Anaerobic and Aerobic
ASTM D5511	Landfill - Single Temperature	Anaerobic and Aerobic
ASTM D5338	Industrial Compost - 60C	Aerobic
ASTM D5988	Soil	Aerobic
ASTM D5210	Sewage Sludge	Anaerobic
None Available	Marine	Anaerobic (PLA, PET, ETC)
OK Compost Home	Home Compost - 35C	Aerobic

## Visual Data

Testing Standard: ASTM D5511 (as reference – landfill environment)



While standards like ASTM D5511 guide testing in landfill environments, a focus on the marine environment is essential due to microplastic pollution. Although additives show promise in degrading microplastics, the long-term ecological impacts in marine ecosystems require further investigation.

## CONCLUSION

Enzymatic biodegradation of polymers exists in all environments where plastic is disposed of due to the plethora of microorganisms that break down different kinds of polymers such as Styrene, Olefins, PET/r-PET, and others, like EVA and TPR. The additives used to enhance the biodegradation of these polymers react as an enhancing biotic mechanism alongside enzymes that are secreted by microorganisms to rapidly decompose the polymer for microbial consumption and transition to CO<sub>2</sub>, CH<sub>4</sub>, biomass and water, using both anaerobic and aerobic respiration. Different test methods show respiration of the aerobes, anaerobes, or both to detect the amount of biodegradation occurring in environments that are usual disposal methods by consumers. Our focus will be on the testing in marine environment because – independent from the disposal behavior of the end consumer – the infamous microplastic, which is generated during every washing cycle, is flushed out in huge amounts every day into the rivers, lakes, and oceans. We have evidence already that our additive works in marine environment for biodegradation of microplastic and we need to further investigate in the efficiency of our additive to solve this biggest problem in pollution of our oceans in near future.

Achieving sustainability in textiles and footwear requires a multifaceted approach. While biodegradable additives present both solutions and challenges, recycled polyester stands out as a proven, eco-friendly alternative. Its energy savings, emission reductions, resource conservation, and circularity make it a crucial element in the path towards a more sustainable future.



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