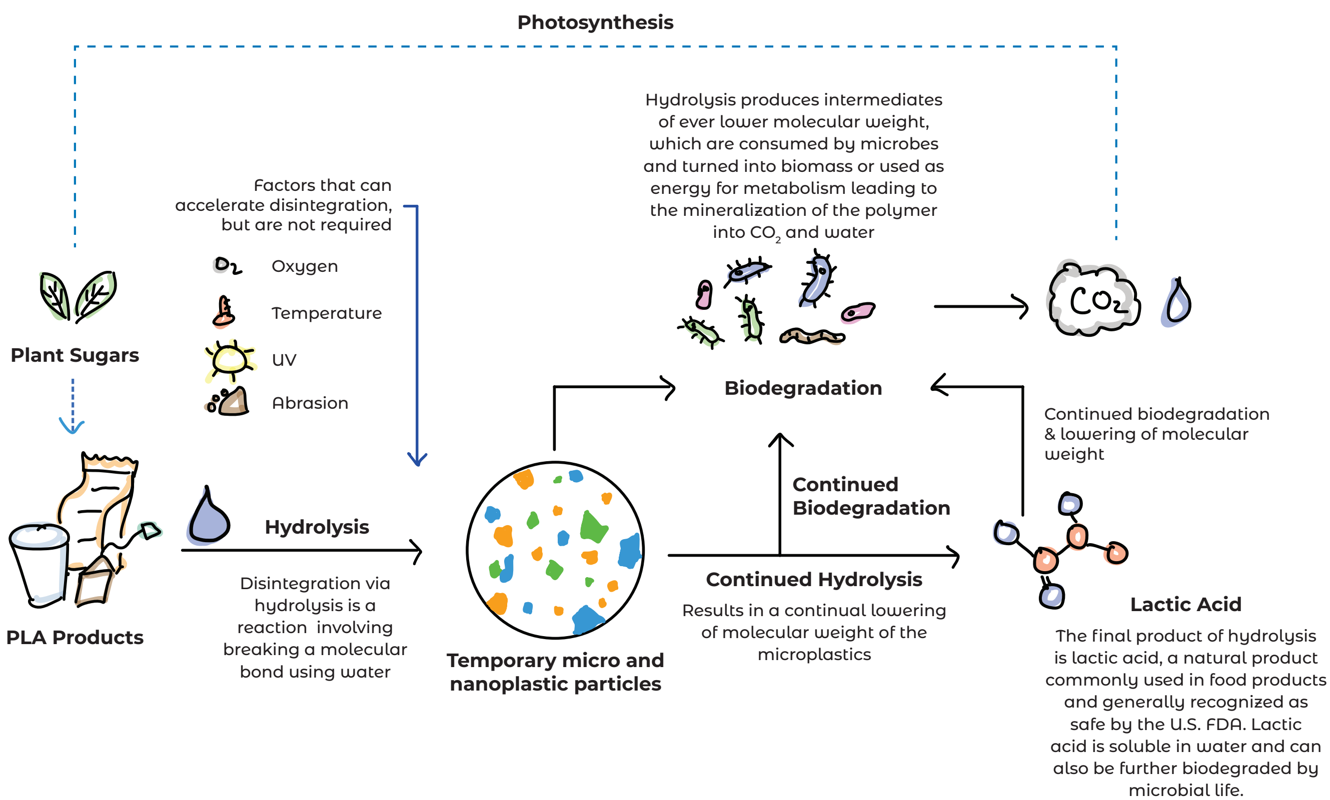
PLA does not create persistent microplastics in the environment

First findings from a new meta-study conducted by HYDRA Marine Sciences on PLA in the environment found that in contrast to non-biodegradable polymers, PLA will eventually fully hydrolyze and biodegrade, meaning no persistent particles should remain and accumulate in the environment.



In recent years, there has been increasing concern about the environmental and health risks of nano- and microplastics. Everything in the natural world, whether organic or inorganic, breaks down over time. Plants biodegrade into humus, which ultimately mineralizes into carbon dioxide and water, closing the natural cycles. However, when synthetic materials like conventional, non-biodegradable plastics wear down, they produce persistent nano- and microplastics that are out of place in the natural environment.

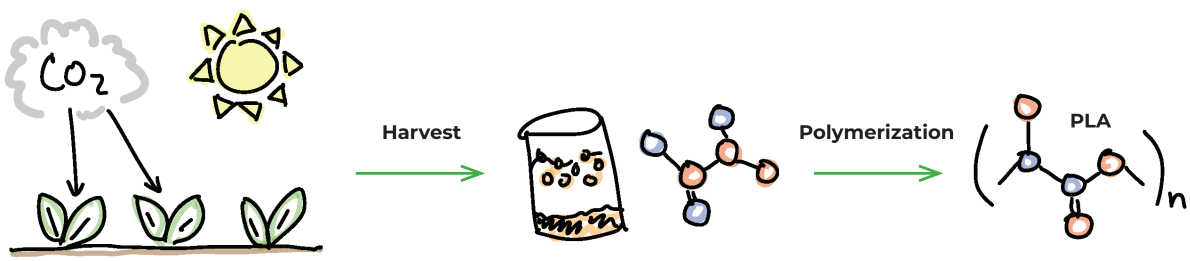
There is rightful concern over the impact of synthetic, persistent microplastics, with questions being asked about the implications of their chemistry, potential toxicity, and long-term fate in the environment. As we begin to understand microplastics' effects on human and environmental health, biobased and compostable polymers like polylactic acid (PLA) are increasingly viewed as a more sustainable long-term alternative.

PLA is Made by Fermenting Renewable Plant Sugars

Producing PLA starts with plants as they sequester atmospheric carbon dioxide in sugar molecules through the process of photosynthesis. Plant sugars are then fermented using microorganisms to produce the monomer lactic acid, a safe, non-toxic substance that is also used to preserve foods and is produced by our bodies during physical exertion. This lactic acid is then polymerized into the polylactide (PLA) biopolymer used to make a wide range of products like cups, cutlery, bin liners, or flexible food packaging.

Because PLA is made from plants that absorb carbon dioxide (CO_2) and water found in nature, when it is composted, hydrolyzed, or biodegraded, the CO_2 and water will return back to nature, making the process circular.

From Nature to Nature



Plants capture & sequester CO_2 into sugars

Plant sugars are fermented into lactic acid & transformed into lactide, that is the building block for polylactic acid (PLA)

Lactide is linked together to form long polymer chains of PLA, which is used to create many applications from cups and tea bags to 3D filament and jars

Littering is Never the Right Option

Littering is never an appropriate option for the products we use every day no matter what they are made from. Whether it's a paper napkin, compostable cup, or fossil-based plastic bottle, these products should always be disposed of within the appropriate waste collection infrastructure. Biobased materials designed for composting should not be littered, but instead collected and processed in local composting infrastructure. Any claims made on products regarding how they degrade in the environment need to ensure that they do not make consumers feel that littering is an acceptable alternative to proper waste disposal.

For industrial composting environments, PLA both as a raw material and in many food packaging applications carry third-party certifications and logos such as **DIN CERTCO, OK compost, or Biodegradable Products Institute (BPI)** to ensure it is clear that these materials have been tested to compost fully according to international standards. As part of the industrial composting certification, PLA was required to pass ecotoxicity testing that ensured it will not negatively affect the quality and safety of compost or harm microbial life.

Key Findings From Meta-Study

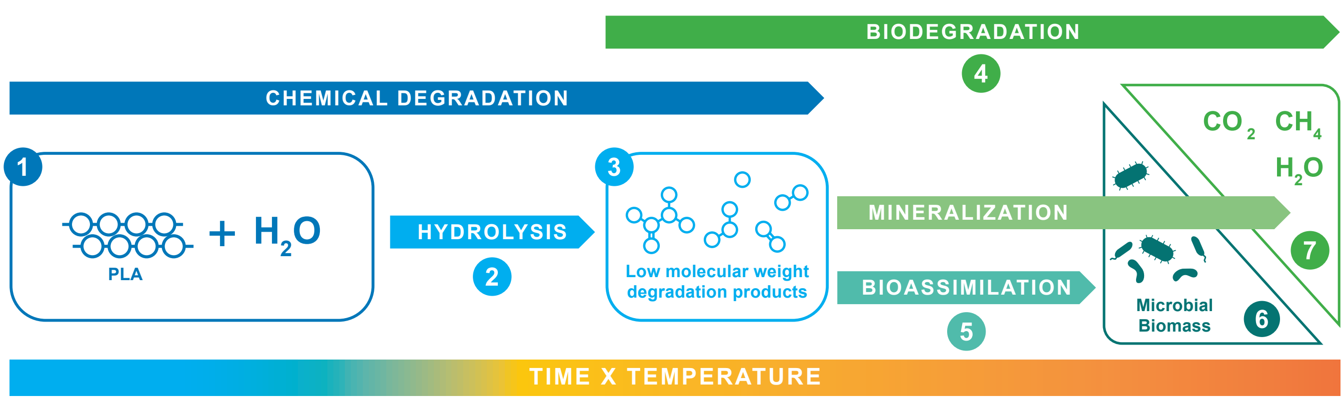
A meta-study recently completed by HYDRA Marine Sciences assessed the current knowledge in publicly available scientific literature and institutional and company reports on polylactide or polylactic acid (PLA) with a focus on the potential formation, persistence, and impact of PLA microplastics in the open environment. The meta-study considered neat PLA only, but not specific articles or products made from or with PLA in which the base polymer may have undergone further treatments and modifications.

Just Add Water: Hydrolysis Prevents Persistency

PLA is a polyester and, due to its molecular structure, is slightly hydrophilic, meaning it has an inherent affinity for water. This property makes the PLA polymer susceptible to attack on its ester bonds by water in a process known as hydrolysis, which leads to the breakdown of the polymer chains over time. Therefore, as long as moisture or water is available, the molecular weight and size of PLA fragments will continually decrease, passing the micrometer and nanometer range, until the polymer chains are so short that the material becomes soluble in water and fragments are not particles anymore. These soluble substances, oligomers, and lactic acid monomers are non-toxic and can be biodegraded by microorganisms into biomass, water, and CO_2. No special additives are needed for PLA to degrade via hydrolysis and subsequent biodegradation.

The rates at which the fragmentation, hydrolysis, and ultimate biodegradation of PLA proceed in the environment depend on PLA properties like crystallinity and environmental variables such as water availability, temperature, and available microorganisms. Sunlight providing heat and UV light, and mechanical abrasion can speed up the degradation but are not a prerequisite. In the technical environment of industrial composting facilities, temperature, and water content are optimized to kill pathogens in food scraps above 60°C, a temperature at which hydrolysis and following biodegradation of PLA are fast. In the open environment, the time to reach complete hydrolysis and eventual biodegradation is assumed to range from months to many decades, depending primarily on temperature and the presence of water.

Micro- and nanoplastics originating from any plastics, as a consequence of mechanical destruction only, will persist and permanently accumulate in the environment. In hydrolyzable and biodegradable polymers such as PLA, degradation will continue as long as moisture is present.



Mechanisms for PLA Degradation: In the presence of water **(1)**, PLA undergoes hydrolysis **(2)** as a pure chemical process of polymer degradation during which low molecular weight intermediates **(3)** such as oligomers and lactic acid monomers are produced. These become soluble and can be biodegraded **(4)**. Microbes take up these oligomers and monomers as food **(5)** and use them to build up biomass **(6)** and as energy for metabolism. Ultimately, this leads to mineralization **(7)** of the original polymer carbon into carbon dioxide, methane, and water.

The PLA polymer itself is not toxic

Neat PLA and its oligomers are widely recognized as non-toxic substances. Lactic acid, the monomer building block of PLA, is classified as Generally Recognized as Safe by the US Food and Drug Administration and EU.

Many PLA grades comply with long-standing global legislation for food contact requirements in the US and EU.

Additionally, specific grades of PLA have been approved and used for decades in medical applications such as sutures, tissue scaffolds, and drug administration substrates. After use in the body, these PLA polymers are absorbed and degraded by the human body.

Beyond the chemistry, the physical impact on the environment and its organisms caused by the presence of a plastic article made from or with PLA is the same as of other plastics with a similar form or shape, be it as an intact object or as micro- and nanoparticles.

However, in contrast to non-biodegradable plastic, which will persist and permanently accumulate as micro- and nanoplastics in the environment, PLA in the environment will hydrolyze into molecules of ever smaller size, becoming soluble and eventually fully biodegraded (mineralized). PLA's non-persistency will allow the environment to recover with time, and its potential impacts can be seen as temporary.

What further research is needed?

The meta-study showed that the available knowledge on the fundamental characteristics of PLA and the hydrolysis process indicates that PLA does not produce persistent microplastics. However, there are still opportunities to improve our collective understanding of the rates and mechanisms by which PLA degrades in the open environment and the resultant impacts with three primary questions identified:

First, what are the hydrolysis rates of PLA at ambient temperatures between 37°C and 0°C in freshwater, seawater, and soils with different humidity? For the open environment, it remains to be demonstrated that degradation does not stop at the level of micro- and nanoplastics but continues and that the molecular fragments resulting from PLA hydrolysis eventually become soluble also at moderate to low ambient temperatures, leaving no solid PLA residues.

Second, does direct biodegradation of PLA occur in the open environment? It is currently unclear whether the depolymerization of high-molecular weight PLA by natural microbes, which has been demonstrated in laboratory experiments, also occurs in nature, and if so, what is their contribution to PLA degradation in the environment.

Third, is there PLA-specific toxicity of PLA micro- and nanoplastics on animal, plant, or microbial life? If so, what are the effect mechanisms and the recovery times?

Download the press release and complete technical summary report containing the results of the meta-study conducted by HYDRA Marine Sciences at:
hollandbioplastics.com

Glossary of Relevant Terms

The study encompassed the properties and processes explained below.

Abiotic refers to things in the environment that are not living.

Biodegradation is the conversion of polymer carbon to CO_2 or CH_4 and new microbial biomass resulting from the action of living cells within no set or expected time frame and can take place in different environments such as soil, marine, or compost.

Biotic refers to things in the environment that are living.

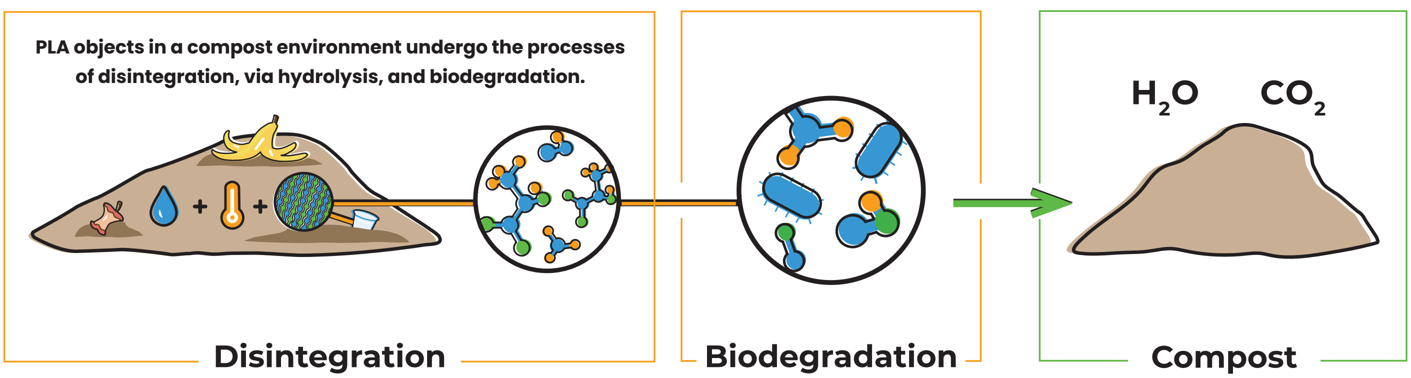
Composting is the process of recycling organic materials, under specific conditions and within a definied timeframe, into an amendment that can be used to enrich soil and plants. Composting of PLA can be viewed as a two step process. First in the disintegration phase, moisture and heat in the compost pile split the polymer chains apart via hydrolysis, creating smaller polymers called oligomers, and finally, the monomer lactic acid. These process of hydrolysis is faster for PLA in compost because of higher, controlled temperatures and controlled moisture levels.

Hydrolysis is a chemical reaction that involves the breaking of a molecule through the addition of water, causing its decomposition or cleavage into smaller components. In the case of PLA, the ester bonds are cleaved through hydrolysis.

Mineralization is the process of converting organic compounds into inorganic compounds through various decomposition procedures.

Oligomers are molecules that consist of only a few repeating units. Basically, these are the short versions of a polymer (which consists of many repeating units).

Persistence of an object or substance in the environment refers to its ability to remain present or endure in the environment over an extended period. It measures how resistant the object or substance is to degradation, breakdown, or removal by natural processes. The threshold for determining whether something is considered persistent can also vary depending on the context and the specific criteria being used.



In the second step, biodegradation, microorganisms in compost and soil consume the oligomers and lactic acid as nutrients. Since lactic acid is widely found in nature, a large number of organisms metabolize lactic acid. The end result of composting is carbon dioxide, water, and humus, a soil nutrient.

Toxicity is the capacity of a substance or agent to cause harmful effects on living organisms, such as humans, animals, plants, and the environment. These harmful effects can range from mild irritation or reversible health issues to severe illness, organ damage or even death. Toxicity can be influenced by the chemical or physical properties of the substance, the dose or concentration of exposure, the duration of exposure, the route of exposure, and individual susceptibility.