Biodegradation, explained

Biodegradation is a natural process that breaks down everything from yard waste to crude oil. The United States Environmental Protection Agency (EPA) defines it as, “A process by which microbial organisms transform or alter (through metabolic or enzymatic action) the structure of chemicals introduced into the environment.” The mechanism varies based on the environment, plastic material and biodegradation rate.

When organic waste decomposes in landfills, it does so in an anaerobic environment, resulting in the production of methane, a highly flammable greenhouse gas that is 23 times more potent than carbon dioxide. As such, aerobic biodegradation, which produces carbon dioxide and organic materials, is desired. In fact, a 2014 EPA report noted that recycling or composting 89 million tons of municipal solid waste reduced carbon dioxide emissions in the atmosphere by 181 million metric tons.

Many bioplastics will biodegrade when composted. They follow a circular economy where sustainable plastics are manufactured from renewable resources. These plastics can be returned to nature when their useful life has ended. In short, a circular economy takes landfills out of the equation. Over the past decade, the plastic industry has been evolving. The number of options for compostable bioplastics has increased, along with the volume of material produced.

Biodegradable plastics: A subcategory of bioplastics

Bioplastics, as a general category, are plastics that are made from renewable biomass or can biodegrade at the end of their lifecycle. Some bioplastics have both attributes, some only one. For example, there are bio-based plastics that are not biodegradable (e.g., bio-based PET) and petroleum-based plastics that are (e.g., PBAT, PCL).

To be truly labeled biodegradable, the plastic must degrade into carbon dioxide, water, biomass and / or mineral salts when exposed to air, moisture and microbes. The materials should not be toxic to the environment. Bio-based materials may also be used as fillers and reinforcements for other biodegradable plastic polymers.

In the United States, the plastic needs to be certified compostable, meaning that it needs to comply with ASTM D6400 as certified by a third party organization such as the Biodegradable Products Institute.

Thus, the term “certified compostable” is more specific than “biodegradable.” All materials are biodegradable given enough time, but claiming a product is “compostable” denotes that it meets requirements of ASTM D6400 or will degrade 90% in 180 days under the specific humidity, temperature and aeration conditions of an industrial composting facility.

The mechanism for biodegradation

Biodegradation can occur under aerobic or anaerobic conditions. Carbon dioxide is produced under aerobic conditions while the same materials will produce methane under anaerobic

conditions (i.e., landfills). The environment or medium in which a plastic is disposed of will affect the possibility and rate of biodegradation.

A biodegradable plastic contains polymers that can be broken down and digested by polymer-degrading microbes in (ideally) aerobic environments where methane isn't a byproduct. If key environmental factors such as temperature and moisture align, then enough microorganisms can adhere to the surface of the plastic, ingest it and enzymatically degrade it.

The mechanism varies between aerobic and anaerobic processes and where the process takes place (e.g., landfill, marine environment or backyard). In general, enzymatic digestion is facilitated by hydrolysis, a two-step process where an enzyme first binds to the ingested polymer to catalyze hydrolytic cleavage. The polymer is then "cleaved" down to molecules with lower molecular weights that are then mineralized to carbon dioxide, water and biomass.

Rates of biodegradation

Biodegradation rates are influenced by the bioactivity of the location, temperature and moisture levels. The disposal site needs to have an environment conducive to the microorganisms needed to break down the plastic, as most biodegradable polymers degrade faster in significantly hot and wet environments.

However, for a biodegradable plastic to properly break down into environmentally friendly components, it needs to be disposed properly. For example, a biodegradable plastic bag thrown into a hedge will take years to properly degrade and even a banana peel needs a minimum of one year. Unfortunately, many biodegradable plastics are improperly discarded in areas that have undesirable environmental conditions, meaning that the products either slowly or never degrade.

A product made with a biodegradable plastic should be designed to biodegrade or compost according to its function. Fortunately, it is possible to create formulas with different biodegradable polymers with various bio-based materials to elongate or shorten biodegradation (or composting) rates, depending on the application.

Consider how quickly compostable products should compost in a backyard after use (remember that composting is a specific form of biodegradation that results in compost). For example, Green Dot Bioplastics developed a compostable horticultural pot. The compostable plastic material was made to compost slowly so the pot could retain its structural integrity on

store shelves but compost in a backyard when used.

Properties of biodegradable plastics

All materials will eventually break down, but what we call “biodegradable plastics” break down into organic components in months or years as opposed to decades or centuries. Each plastic has a chemical composition and material characteristics that dictate which microbes can consume them and ultimately its degradation rate.

Biodegradability as a property does not depend on whether the plastic is sourced from renewable materials. Rather, it depends on the chemical properties of the polymer itself — not whether it is bio-based or petroleum-based. In fact, there are many petroleum-based plastics which are certified compostable.

The line of Terratek® Flex —the market’s first biodegradable elastomer— bioplastics is a good example of a biodegradable plastic which is not fully bio-based. Changing the ratio of natural and synthetic biodegradable polymers can generate a wide variety of properties, allowing for customization of the elastomer to fit the needs of the application.

Also, alloying biodegradable polymers with additives —such as fine wood particles in the Terratek® WC line of bioplastics— can imbue enhanced physical qualities. By altering the ratio of wood and type of biodegradable plastic, different performance (flexibility, rigidity) and aesthetic (color variations, smoother textures) can be achieved.

Read our guide to biodegradation to learn more about the mechanisms behind biodegradation and how the process can be systematized on biodegradable plastics to divert waste from landfills and reduce plastic pollution. Download your copy today.

Guide to biodegradation

Learn how biodegradable plastics can divert waste from landfills.

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