BIODEGRADABLE POLYMERS

Biodegradation is the breakdown of polymer by microbial organisms (such as bacteria, fungi etc.) into smaller compounds. The microbial organisms degrade the polymer through metabolic or enzymatic processes. The biodegradability of a given polymeric material is defined by the chemical structure of the polymer. Photodegradation is often subsequently followed by microbial or biodegradation. Natural products which are susceptible to biological attack are: starch, cellulose etc. Biodegradation of any organic material under controlled aerobic and anaerobic conditions produce **compost**. The process is termed as **composting**. Hence, a plastic that undergoes degradation by microbial action during composting to yield CO_2, H_2O and inorganic compounds, leaving no toxic residue is termed as **compostable plastic**. Ideal conditions for micro organism growth are obtained during the composting process.

Environmental Degradable Polymers

A variety of natural, synthetic, and biosynthetic polymers are bio- and environmentally degradable. **A polymer based on the C-C backbone tends to be nonbiodegradable, whereas heteroatom-containing polymer backbones confer biodegradability**. Biodegradability can therefore be engineered into polymer by the judicious addition of chemical linkages such as anhydride, ester, or amide bonds, among others.

Many polymers that are claimed to be 'biodegradable' are in fact 'bioerodable', 'hydrobiodegradable' or 'photo-biodegradable'. These different polymer classes all come under the broader category of '*environmentally degradable polymers*'.

Thus the classes of biodegradable plastics considered, in terms of the degradation mechanism, are:

1. Biodegradable
2. Compostable
3. Hydro-biodegradable
4. Photo-biodegradable
5. Bioerodable

Biodegradable: American society of Testing and Materials (ASTM) defines 'biodegradable' as: "*capable of undergoing decomposition into carbon dioxide, methane, water, inorganic compounds, or biomass in which the predominant mechanism is the enzymatic action of microorganisms, that can be measured by standardized tests, in a specified period of time, reflecting available disposal condition.*"

In simple words, biodegradation is the degradation caused by biological activity, particularly by enzyme action leading to significant changes in the material's chemical structure. In essence, biodegradable plastics should break down cleanly, in a defined time period, to simple molecules found in the environment such as carbon dioxide and water.

Compostable: Compostable plastics are a subset of biodegradable plastics. Compostable biodegradable plastics must biodegrade and disintegrate in a compost system during the composting process (typically around 12 weeks at temperatures over 50°C). The compost must meet quality criteria such as heavy metal content, ecotoxicity, and no obvious distinguishable residues caused by the breakdown of the polymers.

Hydro-biodegradable and Photo-biodegradable: Two closely linked mechanisms of degradation that are frequently confused with biodegradation are Hydro-degradation (degradation via hydrolysis) and Photo-degradation (degradation via photolysis). Since both mechanisms are often subsequently followed by microbial degradation, confusion of definition frequently occurs. Hydro-biodegradable and photo-biodegradable polymers are broken down in a **two-step** process - an initial hydrolysis or photo-degradation stage, followed by further biodegradation. Single degradation phase 'water- soluble' and 'photodegradable' polymer also exist.

Bio-erodable: Many polymers that claimed to be 'biodegradable' are in fact 'bioerodable' and degrade without the action of micro-organisms - at least initially in the first step. This is also known as abiotic disintegration, and may include process such as dissolution in water, 'oxidative embrittlement' (heat ageing) or 'photolytic embrittlement' (UV ageing).

Some Biodegradable Polymers:

- Starch based products including thermoplastic starch.
- Polyester blends and Polyvinyl alcohol (PVOH) blends.
- Naturally produced polyesters including polyhydroxybutyrate (PHB).
- Renewable resource polyesters such as polylactic acid (PLA).
- Synthetic aliphatic polyesters including polycaprolactone (PCL) and polybutylene succinate (PBS).
- Aliphatic-aromatic (AAC) copolyesters.
- Hydro-biodegradable polyester such as modified PET.
- Water soluble polymer such as polyvinyl alcohol and ethylene vinyl alcohol.
- Photo-biodegradable plastics.
- Controlled degradation additive masterbatches.

Biopolymers and Bioplastics

Biopolymers are polymers which are present in, or created by, living organisms. These include polymers from renewable resources that can be polymerized to create bioplastics.Carbohydrates and proteins, for example, are biopolymers. Many biopolymers are already being produced commercially on large scales, although they usually are not used for the production of plastics.

Bioplastics are plastics manufactured using biopolymers, and are biodegradable.These are also called green plastics. Green plastics are the focus of an emerging industry focused on making convenient living consistent with environmental stability.

Biopolymers and bioplastics are the main components in creating a sustainable plastics industry. These products reduce the dependence on non-renewable fossil fuels, and are easily biodegradable. Also, being biodegradable make bioplastics more acceptable for long term use by society.

Biopolymers

Types of Biopolymers: There are two main types of biopolymers:

(i) those that come from living organisms; and
(ii) those which need to be polymerized but come from renewable resources.

Both types are used in the production of bioplastics.

(i) Biopolymers From Living Organisms

These biopolymers are present in, or created by, living organisms. These include carbohydrates, and proteins. These can be used in the production of plastic for commercial purposes. Examples are listed in the table below.

Biopolymer	Source	Remarks
Cellulose	In plants cellulose is synthesized from glucose. It is the main component of plant cell walls Examples include wood, cotton, corn, wheat, and others	• Cellulose is the most plentiful carbohydrate in the world; 40 percent of all organic matter is cellulose • It has β glucose as the repeat unit. • Cellulose is insoluble in most of the solvents and hence it is converted to its derivatives to make it process able.
Soy protein	Soy protein and zein (from corn) are abundant plant proteins.	• They are used for making adhesives and coatings for paper and cardboard.
Starch	Starch is found in corn (maize), potatoes, wheat, tapioca (cassava), and some other plants.	• Starch is also made up of glucose units and is stored in plant tissues. It is not found in animal tissues. • It has β glucose as the repeat unit • Annual world production of starch is well over 70 billion pounds, with much of it being used for non-food purposes, like making paper, cardboard, textile sizing, and adhesives.
Polyesters	Polyesters are produced by bacteria, and can be made commercially on large scales through fermentation processes. Commercially produced mainly from cow's skimmed milk	• These polyesters are created through naturally occurring chemical reactions that are carried out by certain types of bacteria. • They are now being used in biomedical applications
Casein		• Casein is used in adhesives, binders, protective coatings, and other products

(ii) Polymerizable Molecules

These molecules come from renewable natural resources, and can be polymerized to be used in the manufacture of biodegradable plastics.Some of these are listed in the table below:

Biopolymer	Natural Source	Remarks
Lactic Acid	Beets, corn, potatoes, and others	• Produced through fermentation of sugar feedstocks, such as beets, and by converting starch in corn, potatoes, or other starch sources. • It is polymerized to produce polylactic acid — a polymer that is used to produce plastic.
Triglycerides	Vegetable oils mainly from soybean, flax, and rapeseed.	• Triglycerides are another promising raw material for producing plastics.