Biodegradation 101

True biodegradation is a process in which molecular structure of materials is broken down through metabolic or enzymatic processes. The decomposition process occurs via enzymes secreted by naturally present or naturally occurring microorganism (or microbes) such as bacteria, some fungi, etc. These microbes work alone or in colonies and play a vital role in our ecosystem not just in the biodegradation process. Products made from plant or animal sources such as paper, vegetable scraps, and some plastics that have special ingredients in them will biodegrade. Biodegradation can occur in aerobic (requiring oxygen) or anaerobic (without oxygen) conditions. Biomass (humus) and biogas (carbon dioxide and methane) are the products of a biodegradation process. Under aerobic biodegradation carbon dioxide is the primary gas emitted while in the case of anaerobic biodegradation methane is the primary gas.

Biodegradation in Landfills:
The main bioreaction in landfills is anaerobic biodigestion. Microbes in landfills break down the organic matter and reduce its bulk or mass. To be accurate, it is a series of smaller processes. In the first step, called Hydrolysis (chemical reaction of a compound with water), fermentative bacteria break down the complex insoluble organic molecules into soluble molecules. The second step, Acidogenesis, is a biological reaction where these soluble molecules are converted by acid forming bacteria into volatile fatty acids, hydrogen and carbon dioxide to make them available to other bacteria. What follows is another biological reaction called Acetogenesis, in which the volatile fatty acids are converted into acetic acid, hydrogen and carbon dioxide. In the final stage, Methanogenesis, yet another biological reaction, methanogenic bacteria convert the acetates into methane and carbon dioxide. Hydrogen is consumed in this final stage which continues until the only element left is a nonliving finely divided organic matter called humus (highly nutritional soil made up of carbon, nitrogen, phosphorous and sulfur).

Most landfills these days have approximately 20% moisture levels due to the organic matter in them. Some even have greater moisture levels (as high as 40%) due to moisture or leachate re-circulation to promote/encourage anaerobic biodegradation.

Biodegradable Plastics:
Biodegradable plastics are plastics engineered to decompose in the natural environment. They are either completely or partially derived from renewable sources or are petroleum based with an additive that allows or enhances biodegradation. Plastics containing Eco-One™ fall in the latter category.
**ASTM Test Methods and Standards for Biodegradation of Plastics:**
The American Society for Testing and Materials (ASTM) has established a number of scientific and technological tests to measure true biodegradation in plastic products.

*For anaerobic biodegradation*, the ASTM D5511-02 test method, equivalent to ISO DIS15985 (International Standards), is used for determining biodegradation under high-solids (>30% total solids) conditions. It determines the degree of biodegradation of plastic materials. The test sample is exposed to a methanogenic inoculum cultivated from a wastewater treatment facility’s anaerobic digester operating household waste (methanogens are microorganisms that produce methane as a metabolic byproduct in oxygen-deprived conditions). Incubation (in dark) is typically for 15 days. During this time, the volume of carbon dioxide and methane emitted from the biodegrading test sample relative to a positive control (typically cellulose), a negative control (same resin without the additive), and the inoculum alone is measured at different intervals. At the conclusion of the test, the mass (weight) of the remaining solid test sample and all the control samples is determined. ASTM D5526 is used for determining biodegradation under accelerated landfill conditions. Neither standard stipulates how long it should take for a certain amount of biodegradation.

*For aerobic biodegradation (what happens in a commercial composting site)*, ASTM D5338 test method is used for determining biodegradation under controlled composting conditions while ASTM D6400 sets the specification for compostable plastics. According to the ASTM, for plastic to be considered compostable it must meet 3 criteria:

- It must biodegrade as in be able to break down to carbon dioxide, water and biomass
  - It requires more than 60% of the organic carbon in homopolymers and 90% in copolymers to be converted to carbon dioxide within 180 days

- It must disintegrate, that is, it should be visually indistinguishable after breaking down and look like compost
  - Less than 10% of original dry weight should remain on a 2mm screen after 120 days

- No adverse impact on ability of compost to support plant growth (and not introduce unacceptable levels of heavy metals or toxic substances into the environment)
If plastics are biodegradable in biologically active landfills, per ASTM D5511, they may not necessarily be biodegradable ("compostable") in municipal and industrial composting facilities per specifications outlined in ASTM D6400. The reverse is also true. Compostable plastics may not biodegrade in a landfill. Commercial composting sites grind material and turn over the piles at high temperature to achieve biodegradation and disintegration. Home composting takes at least 2 times as long to achieve the same results.

**Degradable and Biodegradable Plastics:**
Plastics may be degradable but not necessarily biodegradable. There are two primary differences between ‘degradable’ and ‘biodegradable’. First, one or more - heat, moisture, oxygen and/or UV exposure - most often cause the degradation of a degradable product. It is a chemical and/or mechanical process. Microorganisms on the other hand degrade a biodegradable product through a biochemical process. Secondly, degradable products tend to take much longer to break down into carbon dioxide, biomass and water. When degradable plastics break down into smaller molecules, they may eventually be small enough to be consumed by microorganisms and so biodegradation may occur. It is very likely they may leave metals, toxins and polymer residue in the environment.

**Mechanism of Biodegradation Using Eco-One™:**
Eco-One™ is a proprietary blend of organic compounds that are melt-compounded into a masterbatch carrier resin and then pelletized. The pelletized masterbatch is subsequently melt-blended into the final base resin (LDPE, HDPE, LLDPE, PP, PET, PS, PC etc) by the end-user during their manufacturing process (extrusion, injection molding, blow molding, etc.). The properties of the base resin or final product are not altered during manufacturing, storage and usage. In other words shelf life and performance-during-use remain unaffected. Only when the product containing Eco-One™ is exposed to an environment that is moist and has microorganisms, such as a biologically active landfill, will the polymer alteration process begin. This has been confirmed by Gel Permeation Chromatography (GPC) test on samples treated with Eco-One™ both before and after exposure to conditions of the ASTM D5511 test.

Eco-One™ renders the water-repellant base resin more water-loving (hydrophobic to hydrophilic). As a result, the moisture and microorganisms present in landfills and composters are attracted to the plastic and begin to attach to the plastic. These initial “colonists” facilitate the arrival of more and diverse microorganisms, collectively forming a film (called biofilm) that adheres to the plastic. Formation of biofilm is a prerequisite
and humidity is critical in the formation of this biofilm. Eco-One™ having facilitated the formation of biofilm further aids in promoting the growth of microorganisms within the biofilm. The base polymer now becomes the primary source of nutrients for the microorganisms. Likeliest points of attack are at or near the end of polymer chains and/or branches. Eco-One™ causes the molecular structure of the plastic to expand (or swell) creating space for more organisms to penetrate and feast on their nutrient source. All this time, enzymes secreted by bacteria are serving as chemical signals to other bacteria that get drawn to the plastic as a result. This bacterial communication process is known as *quorum sensing*. The feast, which entails breaking down the chemical bonds, continues the biodegradation process.