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The Semantics of Biodegradation versus Bio-assimilation

Biodegradation

Complete biodegradation is defined as the process by which organic substances are decomposed by micro-organisms (mainly aerobic bacteria) and accumulated into simpler substances such as carbon dioxide, water and ammonia.

The United States Environmental Protection Agency defines biodegradation as,

“A process by which microbial organisms transform or alter (through metabolic or enzymatic action) the structure of chemicals introduced into the environment.”

Basically, organic (carbon-based) material is changed through chemical processes from complex molecules into simpler molecules, eventually returning the molecules into the environment. For example, a banana peel can be reduced from cellulose to water, carbon dioxide gas, and humus.

In nature, different materials biodegrade at different rates. To be able to work effectively, most microorganisms that assist the biodegradation need light, water and oxygen. Temperature is also an important factor in determining the rate of biodegradation. This is because microorganisms tend to reproduce faster in warmer conditions. Biodegradation can be measured in a number of ways. Scientists often use respirometry tests for aerobic microbes. First one places a solid waste sample in a container with microorganisms and soil, and then aerate the mixture. Over the course of several days, microorganisms digest the sample bit by bit and produce carbon dioxide – the resulting amount of CO_2 serves as an indicator of degradation. Biodegradation can also be measured by anaerobic microbes and the amount of methane or alloy that they are able to produce. In formal scientific literature, the process is termed bio-remediation.[2]

Approximated time for compounds to biodegrade in a marine environment[3]

Product	Time to Biodegrade
Apple core	1–2 months
General paper	1–3 months
Paper towel	2–4 weeks
Cardboard box	2 months
Cotton cloth	5 months
Plastic coated milk carton	5 years
Wax coated milk carton	3 months
Tin cans	50–100 years

Aluminum cans	150–200 years
Glass bottles	Undetermined (forever)
Plastic bags	10–20 years
Soft plastic (bottle)	100 years
Hard plastic (bottle cap)	400 years

Bio-assimilation

The term 'Bio-assimilation' as it applies to the area of reclamation can be defined as ' The accumulation of a substance within a habitat or specific environment'. It is the complete conversion of a substance into biomass by biochemical processes. In other words, it has to satisfy requirements that the main chain must be scissored by living microorganisms returning the molecules into the environment from which it came.

Plastics

There are two main types of biodegradable plastics in the market: hydro-biodegradable plastics (HBP) and oxo-biodegradable plastics (OBP). Both will first undergo chemical sodium carbon dioxide degradation by hydrolysis and oxidation respectively. This results in physical disintegration. These smaller fragments are then more amenable to biodegradation.

OBPs are made by adding a small proportion of compounds of specific transition metals (iron, manganese, cobalt and nickel are commonly used) into the normal production of polyolefins such as polyethylene (PE), polypropylene (PP) and polystyrene (PS). The additives act as catalysts to speed up the normal oxidative degradation, increasing the overall process by up to several orders of magnitude (factors of 10).
The products of the catalyzed oxidative degradation of the polyolefins are precisely the same as for conventional polyolefins because, other than a small amount of additive present, the plastics are conventional polyolefins. Many commercially useful hydrocarbons (e.g., cooking oils, polyolefins, many other plastics) contain small amounts of additives called antioxidants that prevent oxidative degradation during storage and use. Antioxidants function by 'deactivating' the free radicals that cause degradation. Lifetime (shelf life + use life) is controlled by antioxidant level and the rate of degradation after disposal is controlled by the amount and nature of the catalyst.
Since there are no existing corresponding standards that can be used directly in reference to plastics that enter the environment in other ways other than compost - i.e. as terrestrial or marine litter or in landfills, OBP technology is often attacked by the HBP industry as unable to live up to the standards (which are actually the standards for composting). *It has to be understood that composting and biodegradation are not identical.*

HBPs tend to degrade and biodegrade somewhat more quickly than OBP, but they have to be collected and put into an industrial composting unit. *The end result is the same -* both are converted to carbon dioxide (CO_2), water (H_2O) and biomass. *OBP are generally less expensive, possess better physical properties and can be made with current plastics processing equipment*. And, HBP emits methane in anaerobic conditions, but OBP does not.
Polyesters play a predominant role in hydro-biodegradable plastics due to their potentially hydrolysable ester bonds. HBP can be made from agricultural resources such as corn, wheat, sugar cane, or fossil (petroleum-based) resources, or blend of the two. Some of the commonly used polymers include PHA (polyhydroxyalkanoates), PHBV (polyhydroxybutyrate-valerate), PLA (polylactic acid), PCL

(polycaprolactone), PVA (polyvinyl alcohol), PET (polyethylene terephthalate), etc. It would be misleading to call these "renewable" because the agricultural production process burns significant amounts of hydrocarbons and emits significant amounts of CO_2. *OBPs (like normal plastics) are made from a by-product of oil or natural gas, which would be produced whether or not the by-product was used to make plastic.*
HBP technology claims to be biodegradable by meeting the ASTM D6400-04 and EN 13432 Standards. However, these two commonly quoted standards are related to the performance of plastics in a commercially managed *compost* environment. ***They are not biodegradation standards***. Both were developed for hydro-biodegradable polymers.

Conclusion

The terms 'biodegradable' and 'bio-assimilation' in their purest and most accurate definitions are in fact, virtually the same. The misunderstanding comes from the intended misuse of the word 'biodegradable' as it applies to marketing of products. This is an example of advertising professionals adopting and redefining a specific word to represent something other than its true meaning. It is green washing at its very best. Existing ASTM standards were written to support a false definition of the word "biodegradable" and published as fact. Those standards are now about to be modified in a manner which reflects science rather than marketing.

The simple facts are:

- Biodegradation does not require composting
- Bio-assimilation does occur in a composting environment
- Oxo-biodegradable technology does not ensure complete biodegradation
- Bio-assimilation technology does ensure complete biodegradation