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College of Agricultural Sciences Cooperative Extension
Agricultural and Biological Engineering

Degradable Plastics

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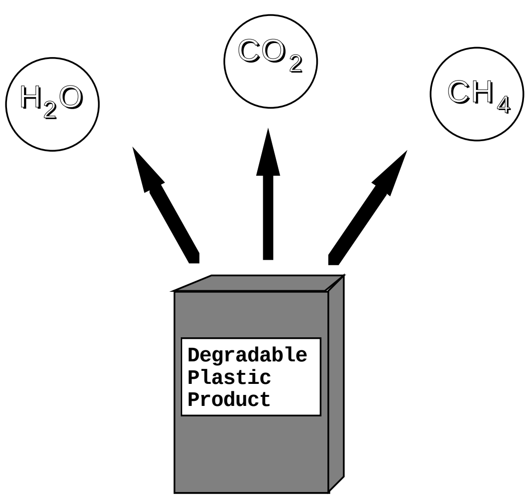
From engineering applications to everyday use, plastics provide many benefits such as strength, durability, and convenience of use. Ironically, it is these same properties that have made plastics such a problem in the waste stream. Each year, forty-six billion pounds of plastic material is produced, but only three percent of that material is recycled; the remainder usually becomes litter or is landfilled. Because plastics are designed to resist degradation, they can become permanent residents at landfills. Littering not only threatens wildlife and marine life, but it also damages the aesthetic environment. Besides littering, other improper methods of disposal, such as burning or burying the material at home, releases harmful or toxic pollutants into the environment.

As the public becomes sensitive to many waste management issues, an increasing number of consumers, industry members, and legislators are searching for environmentally safer products. This search has resulted in strong interest in "degradable" plastics.



The Degradation Process

Generally, most materials will degrade given enough time. The difference between degradable and non-degradable products is that degradables are designed to be less resistant to decomposition. This is an odd turn of technology for the plastic industry, which has spent years working to make plastics durable, inert, impermeable to gas and water, and resistant to chemical and microbial attacks—properties that have traditionally prevented plastics from degrading.

The theory behind degradable plastics is based on the toughness of the plastic material, which is caused by long chains of carbon and hydrogen called polymers. If these polymer chains are reduced in size, then the plastic material should lose its strength, become brittle, and eventually degrade into harmless by-products such as carbon dioxide and water.

Basically, there are two methods of degradation: photodegradation and biodegradation. (For an in-depth technical description of these processes, see Fact Sheet C-17.)

Photodegradation

The photodegradation process is derived from the fact that *all* plastics have molecular irregularities which absorb ultraviolet (UV) light. When exposed to a certain amount of sunlight, these irregularities cause the plastic material to degrade.

In the photodegradation process, this naturally occurring degradation is accelerated by the addition of a sun-sensitive component called a *promoter*, typically carbon monoxide or vinyl ketone. The promoter is injected at intervals into the polymer chain, where sunlight is absorbed by the material and converted into energy. This energy from the sunlight breaks down the backbone of the long polymer chain, leaving behind a shorter, weaker chain that biodegrades over a period of time. Studies have indicated a 95 percent property loss after photodegradable materials have been exposed to direct sunlight for a year.

Biodegradation

The biodegradation process is less understood than the photodegradation process. A natural polymer, such as starch or sugar, is added to the plastic material. This natural polymer causes the material to break down when exposed to an appropriate organic environment. The two forms of biodegradation are *macrodegradation* and *microdegradation*. Macrodegradation is caused by the consumption of the plastic material by animals or insects, such as wood lice. Microdegradation is caused by the consumption of the material by microorganisms, such as fungi, bacteria, and yeast. Typically, the biodegradation process refers to consumption by microorganisms, which can occur by any of the following methods:

**Biophysical Breakdown:* cell growth causes mechanical damage to the polymer chain

**Biochemical Breakdown:* a substance produced by the microorganism acts on the polymer chain

**Direct Enzymatic Attack:* microorganisms release an enzyme that attacks the polymer chain, causing the chain to splinter and break down

The biodegradation process generally takes longer to complete than the photodegradation process. However, both photodegradation and chemical degradation need to be further reduced by biodegradation in order to decompose into only natural by-products.

Degradable Plastics in the Marketplace

The rapid evolution of degradable plastics has prompted research, product development, and marketing to occur at the same time. Even though research is only in the early stages, degradable plastics already account for approximately two percent of the total plastic production in the United States, which is expected to rise to four percent by the year 1996.

Degradable plastics have found most of their popularity in single-use, short-lived items that are difficult to collect and recover by recycling or incineration. Some products being marketed as degradable include disposable diapers, food packaging, shopping bags, compost and sandwich bags, mulch film, six-pack beverage rings, and coatings for paper and paperboard. Plasticizers—chemicals that add flexibility to plastics and enable them to be molded products—are increasingly being made of degradable material.

One obstacle facing the degradable plastics industry is competition with non-degradable plastics producers. The price of degradable plastics typically ranges from two to three dollars per pound, compared to non-degradable plastics which costs approximately $ .50 per pound. The high price of degradable plastics is due to research costs and to unstable product markets. However, several economic factors may increase the production and lower the costs of degradables. These factors include the environmental advantage, economies of scale, increased competition, and regulatory mandates requiring the use of degradables for certain applications.

Managing Degradable Wastes

Despite the relatively high costs of degradables, the primary challenge currently facing the degradable plastics industry is educating end users. This means informing the end users about the benefits, or lack of benefits, of degradable plastics within a community's municipal solid waste management program. Most end users believe that degradable plastics will reduce the amount of waste that a community generates. Unfortunately, this is not true. Degradable plastics are still wastes that need to be properly managed by a combination of composting, recycling, incineration, and landfilling.

Composting

Composting seems to be the most promising for degradable plastics because the composting process is designed to degrade wastes. There are, however, obstacles that make many communities reluctant to accept plastics for composting.

One difficulty is locating a nearby facility that can safely, legally, and effectively collect and compost degradable plastic materials. Currently, only one to two percent of the municipal solid waste stream in North America is composted, and composting facilities are required by law to have a separate permit in order to accept plastic materials. Most facilities are only permitted to accept yard wastes; very few are permitted to accept other forms of municipal solid wastes, including degradable plastics. These separate permits are required because there are still many unanswered questions concerning visual and toxic contamination that the plastic material may introduce into the compost pile.

Visual contamination—the presence of residual plastic material in the compost pile—reduces the marketability and usability of the compost. To reduce the amount of visual contamination, the plastic material should be completely consumed in the composting process, producing only natural by-products such as carbon dioxide, methane, water, and biomass. The breakdown of the material should occur within a reasonably short period of time, typically 60 days. The need to know the precise timing and amount of decomposition is a very important concern of the degradable plastic industry. The degradation of plastics can be significantly affected by environmental factors, including temperature, amount of sunlight, and weather conditions. Besides environmental factors, the amount of degradation can also depend on the location of this material within the compost pile; some studies have indicated that degradable plastic material located in the middle of the pile degrades slower than the exposed material on the outside.

Toxic contamination is an issue that must be addressed before degradable plastics will be fully accepted for composting. Many of the additives in plastic material—plasticizers, coloring pigments, stabilizers, and promoters—can contain heavy toxic metals, which can make the entire compost pile unusable. In addition, the presence of toxic metals, mainly cadmium and lead, in *any* plastic material is still an important concern. These questions about both visual and toxic contamination have slowed consumer acceptance of degradable plastics in many community and home composting piles.

Recycling

The question of contamination not only pertains to composting degradable plastics, but also to recycling them. Many recyclers fear that degradable products and their additives will contaminate batches of recycled resins. For example, starch-based biodegradable plastics form clumps in the melt, and degradable additives in the products could release toxic metals during reprocessing. These types of problems can make the recycling process difficult and expensive. Yet, members of the degradable plastic industry and some recyclers of polyethylene claim that the degradability of the plastic material does not affect the process or end products. In fact, degradable plastics may actually help recycling efforts by reducing some of the problems associated with low-value, non-recyclable products or products that cannot be economically and efficiently recycled.

Landfilling

Many end users believe that degradable plastic products will degrade in landfills; however, degradation in modern landfills usually *does not* occur. Landfills are designed to block out air, water, and sunlight. While blocking out these natural elements prevents landfill contaminates from entering soil and drinking water supplies, it also prevents degradation from taking place. Even highly organic materials, such as newspaper and food scraps, can take years to fully degrade in landfills. Because plastic material is tough and durable, it is even less likely to degrade. Also, the plastic laminate (coating) on some paper products can further reduce the speed of degradation.

It is important to note, however, that not all landfills operate at optimal conditions, and some natural elements may enter certain landfills. The wide variations in the construction and operation of landfills make it difficult to draw a general conclusion about the degradability of plastics in landfills.

Marine Disposal

Even though marine disposal is not typically considered a method to manage wastes, a million tons of plastic wastes are dumped each year into the ocean, accounting for 69 percent of the plastic litter that washes up on the beach. Some ocean wastes include discarded fishing gear, packaging materials, and medical wastes. Disposing of these materials at sea poses a threat to animals and marine life, including several protected species. These animals can become entangled in or ingest the waste material, which impairs their growth and can result in death. There is a possibility that degradable plastics can reduce this threat by decreasing the strength and life span of the plastic material.

To decrease the amount of non-degradable marine disposal, the Marpol Law of the Sea Agreement signed by the United States requires that the government stop dumping non-degradable plastics at sea by the year 1993. Currently, there are several water-soluble polymers available in the marketplace, but the Coast Guard has included a provision in the Agreement, limiting the use of degradable plastics disposed of at sea to those made from sea products.

Programs and Standards

There are several efforts underway to help answer concerns about the degradation process and its place in a community’s waste management program. The

American Society for Testing and Materials (ASTM) developed Subcommittee D-20.96 on Environmentally Degradable Plastics. This committee is working to develop definitions of certain terms and standards for testing degradable plastics (See Table 1). Copies of these standards can be purchased by contacting:

The American Society for Testing and Materials
1916 Race Street
Philadelphia, PA 19803
(215) 299-5400

Another effort to help the development of degradable plastics is a research program started by a consortium of 10 companies, the National-Corn Growers Association, and the Environmental Defense Fund. This $480,000 funded program allows these companies and organizations to share their own work and to help direct further research. For more information, contact:

National Corn Growers Association
1000 Executive Parkway
Suite 105
St. Louis, MO 63141-6377
(314) 275-9915

Environmental Defense Fund
257 Park Avenue South
New York, NY 10010
(212) 505-2100

Summary

Despite their promising benefits, degradable plastics are still in the developmental stage of technology and market growth. This makes it increasingly important that the public, industry, and legislators keep the concept of degradable plastics apart from the facts. Further research will help sort out these facts and bring degradable plastics to their proper place in a community's waste management program.

PSU/94

Std. No.	***Description***
D5210-91	Standard Test Method for Determining the Anaerobic Biodegradation of Plastic Materials in the Presence of Municipal Sewage Sludge
D5209-91	Standard Test Method for Determining the Aerobic Biodegradation of Plastic Materials in the Presence of Municipal Sewage Sludge
D5208-91	New Standard Practice for Operating Fluorescent UV and Condensation Apparatus for Exposure of Photodegradable Plastics
D5152-91	Practice for Water Extraction of Residual Solids from Degraded Plastics for Toxicity Testing
D5071-91	New Standard Practice for Operating Xenon Arc-Type Exposure Apparatus with Water for Exposure of Photodegradable Plastics
D5247-92	Standard Test Method for Determining the Aerobic Biodegradation of Degradable Plastics by Specific Microorganisms
D5338-92	Standard Test Method for Determining Aerobic Biodegradation of Plastic Materials Under Controlled Composting Conditions

Table 1: Approved Standards of ASTM Subcommittee D20.96 on Environmentally Degradable Plastics.

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