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Project Summary

Weatherability of Enhanced Degradable Plastics

Anthony L. Andrady

The performance and the associated variability of several selected enhanced degradable plastic (EDP) materials was assessed under a variety of different exposure conditions. Several commercially available materials, including both photodegradable and biodeteriorable plastics, were exposed to direct sunlight, soil burial, and marine and freshwater exposure. Laboratory exposure consisted of accelerated weathering by Xenon Arc Weather- Ometer* and laboratory-accelerated soil burial.

Results of this study showed the elongation at break and the energy to break to be the tests most sensitive to weathering-induced changes.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The use of plastics in packaging and other consumer applications has led to a growing fraction of post-consumer plastic waste in the municipal solid waste stream. The United States presently generates over 195 mil tons of municipal solid waste annually; of this, about 8% by weight is plastics.

Recently, scientific data have been gathered to suggest that plastic waste may be hazardous to wildlife, especially marine life, e.g., sea lions and fur seals have been entangled in plastic debris and marine turtles and birds have eaten plastic litter.

With EDPs, the intention is to accelerate the breakdown of plastic material by chemically modifying the polymer, synthesizing new environmentally degradable thermoplastics, and incorporating additives into commodity plastic materials to achieve faster breakdown.

The goals of this study were to:

- study the performance and the associated variability of several EDP materials under a variety of different geographic exposure conditions, including air, sea, and soil, as well as laboratory exposure conditions,
- better understand the underlying factors governing enhanced degradability in EDP systems including the effect of enhanced degradation on the water vapor and gas permeability of selected EDPs; also study activation spectra of the enhanced photodegradable plastics to identify the spectral regions most effective in bringing about light-induced degradation.
- study the major products formed during enhanced degradation of EDP materials and assess the toxicity of such products, and
- study the effects on the quality of recycled products when a small fraction of partially degraded EDP materials are included in a recycling stream

* Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Procedure

A representative set of sample types was selected from commercially available materials by using several criteria such as type of resin and potential use of the material:

- ethylene/carbon monoxide (1%) copolymer (6P) selected because of its use as a beverage ring holder in six-pack packaging,
- polystyrene blended with copolymer (PS),
- low-density polyethylene containing metal prooxidant compounds (PG) and low density polyethylene/6% starch blends with and without metal prooxidant compounds (ADM) used in agricultural mulch films.
- linear, low-density polyethylene/ polycaprolactone (20%) blends (PCL),
- poly (hydroxybutyrate valerate) film (BP) (limited testing).

The materials were tested in sheet or film form. Materials of low-density polyethylene as close in formulation as possible to the tested materials were used for control.

The different types of exposure included:

- outdoor exposure at five locations
- direct weathering
- soil burial
- floating and sediment exposure in marine and in fresh-water environments
- field soil burial
- laboratory accelerated weathering (Weather-Ometer)
- laboratory-accelerated burial in different soils

In general, photodegradable samples were exposed to direct weathering and to marine and freshwater floating environments, and biodegradable samples were exposed to marine sediment and soil burial. Other testing included tests for tensile properties, yellowness index, tumbling friability, gel permeation chromatography for molecular weight measurements, water vapor transmission rate, thermogravimetry to rapidly determine starch content of polyethylene/starch blends, gas transport properties, and toxicity.

Basic methodologies proposed in the Quality Assurance Project Plan were closely followed.

Detailed findings of all tests are given in the full report.

Results and Conclusions

The study of the possible toxicity of degradation products of the EDPs was limited to selecting a toxicity screening test and to determining if the leachate showed marked toxicity. Data from the modified standard tests did not show toxicity at realistic levels of leachate concentration.

A limited study was done of the effect of including a small fraction of partially degraded EDP in the composition of a recycling stream. The exposed degradable plastics could not be tested before entering the stream because the films were too brittle and thin to be tested. When some unexposed films were used, both the strength and flexibility of the extruded film were enhanced by low concentrations of degradable material.

The rate of photodegradation of six-pack ring material (6P) was not affected significantly by temperature (65°C to 85°C), but the degradation of both PG and ADM materials was temperature dependent at the same temperatures.

A rapid thermogravimetric method to determine starch content of a polyethylene/ starch blend material was developed and found suitable to study partially degraded films and to determine residual starch content in starch/polymer systems.

The activation spectra for loss in tensile elongation at break (the most sensitive tensile property to degradation) was studied for certain materials. The region of the sunlight spectrum most likely to cause degradation was found to be <340nm.

In studying the effect of enhanced degradation on gas permeability in PG and 6P materials, where the photodegradation occurred at an accelerated rate, carbon dioxide transport rates changed markedly with duration of exposure. In 250 hr of Weather-Ometer exposure, 6P sample permeability decreased 40% and PG sample permeability increased about 275%. This is explained by increased crosslinking and generation of sol material in the PG material during oxidation and/or crystallinity of the 6P material during oxidation.

Water vapor transmission rate was affected by enhanced photooxidative degradation. A 10-day weathered sample of ADM increased its water vapor transmission rate 30%. The increased rate for PG samples was measured as a function of time. Forty days of laboratory exposure to aerobic soil did not, however, change the water vapor transmission rate of PCL film.

When enhanced photodegradable plastics were exposed at outdoor locations:

- the tensile test parameters most sensitive to weathering changes were elongation at break and energy to break;
- the rate of breakdown markedly increased as indicated by loss in extensibility, with the ratio between enhanced degradable and control materials being called the "enhancement factor;"
- the geographic location influenced the photodegradability, with different degradation rates for different types of EDPs at the different sites;
- a moderate correlation existed between loss of extensibility and the amount of light received;
- the yellowness index increased with exposure; and
- nearly all materials degraded faster in the Weather-Ometer studies but not at the same rates.

When enhanced photodegradable plastics were exposed to marine and fresh water:

- the loss of extensibility was lower for the floating samples than for the terrestrial exposure (possibly because of lower temperatures and shielding from light by foulants), with the breakdown of the marine control samples being, in some instances, barely measurable;
- in Miami, FL the degradation rates and enhancement factors were faster than they were in Seattle, WA;
- in Miami, the breakdown rate at sea was 2-1/2 times that for land exposure of enhanced degradable polystyrene foam materials and, for the controls, it was about the same;
- BP samples under sea sediment degraded at a rate more than 30 times that of the film exposed on land, and the fresh-water sediment degradation rate was about 85% of that at sea; and
- after 21 wk of marine sediment and 8 wk of fresh-water sediment exposure, PCL samples lost 50% of their extensibility.

When the EDP materials designed for biologically mediated breakdown were exposed outdoors under aerobic soil burial conditions, the time was too short to observe any significant disintegration of the PCL and ADM materials, but under similar conditions, BP samples degraded rapidly and were embrittled by 29 days. When these materials were exposed to laboratory-accelerated soil burial, there was no marked deterioration during the 10 wk observation time.

Recommendations

Data are needed from additional land and marine locations and from exposures at different seasons of the year to complete this documentation of photodegradable plastics. Longer observation periods are needed to establish limits of the performance of biodegradable and biodeteriorable films, especially the poly-

ethylene/starch system. Further toxicity studies are needed, as is a full-scale recycling study that involves including small amounts of degraded post-consumer EDPs in a recycling stream.

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Anthony L. Andrady is with Research Triangle Institute, Research Triangle Park, NC 27709.
***Lynnann Hitchens** is the EPA Project Officer (see below).*
The complete report, entitled "Weatherability of Enhanced Degradable Plastics" (Order No. PB93-229 789/AS; Cost: $44.50, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Risk Reduction Engineering Laboratory
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

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