TECHNICAL BULLETIN

METHODS FOR MEASURING THE BIODEGRADATION

POLINTER

1 Definitions of biodegradation [1]

1.1 Degradable polymers

A degradable polymer is one which suffers a significant change in its chemical structure under specific environmental conditions. The initiation and propagation of the degradation can be induced chemically, by effects of heat, light (UV) or biologically.

1.2 Mechanism of materials degradation

a) Chemical degradation.
b) Degradation by environmental agents of a covering material.

1.3 Photodegradation

c) Thermal degradation.

1.4 Biodegradation

Degradation caused by biological activity, specifically by enzymatic action which results in a significant change in the structure of a material. The main agents involved are bacteria and fungus.

1.5 Primary or partial biodegradability

It is the alteration of the chemical structure which results in loss of specific properties of the polymer.

1.6 Final biodegradability

It leads to the mineralization with formation of CO_2 (aerobiosis), CH_4 (anaerobiosis), water, minerals and biomass.

2 Definition of biodegradable plastics or polymers [1]

2.1 American Society for Testing and Materials (ASTM subcommittee D20)

It is a degradable plastic is in which the degradation results from the action of microorganisms of natural occurrence.

2.2 International Standards Organization (ISO 472)

It is a plastic designed to suffer a significant change in its chemical structure under specific environmental conditions resulting in the loss of some properties, measured by standard methods. These changes result from the action of microorganisms of natural occurrence.

2.3 German Institute for Standardization (DIN 103.2)

It is a plastic material in which all its organic components undergo a complete process of biodegradation. The environmental conditions and the biodegradation rates are determined by standardized methods.

2.4 European Committee for Normalization (CEN)

It is a degradable material whose degradation depends on the action of microorganisms. The material is mineralized.

2.5 Japanese Society of Biodegradable Plastics

They are polymers which are changed to lower molecular weight compounds where at least one step in degradation occurs by microorganisms of natural occurrence.

3 Requirements for the biodegradability of polymers [1]

3.1 Presence of enzymes and microorganisms

a) Induction of the synthesis of the degradative enzyme by the polymer,
b) Optionally, a secreted constituted enzyme.

3.2 Biotic availability of the polymeric structure

a) Crystallinity of the polymer,

b) Accessibility of the enzyme to the bond,
c) Formation of metabolizable products by the microorganism.

3.3 Abiotic environmental factors

a) Oxygen level,
b) Availability of nutrients,
c) Suitable temperature,
d) Appropriate pH.

4 Biodegradation – Polymer Structures relationship [1]

a) Molecular weight of the polymer.
b) Presence of susceptible bonds to enzymatic breakdown.
c) Stereochemistry of the polymer.
d) Hydrophilic-hydrophobic character of the polymer.
e) Flexibility of the polymer chains.
f) Amorphous regions.
g) Length of the monomeric units and thus the crystallinity.
h) Size, number and shape of the crystallites in semi-crystalline polymers.

5 Standards and methods of Biodegradation [2] [3]

Nowadays in Venezuela there are no standards, or test methods, which specifically apply to biodegradable plastics. However, internationally they have developed standards that regulate and measure the degradation rate and biodegradation processes. The main international organizations that have established standards or test methods are:

- American Society for Testing and Materials (ASTM) (www.astm.org),
- Institute for Standards Research (ISR),
- International Standards Organization (ISO) (www.iso.org),
- European Standardization Committee (www.cenorm.be) (CEN),
- German Institute for Standardization (DIN), and
- Organic Reclamation and Composting Association (ORCA) (Belgium).

5.1 American Society for Testing and Materials (ASTM)

A family of ASTM standards covers the study of the deterioration of the plastic physical properties under a variety of specific environmental conditions including simulated composting environments (D5509, D5512), simulated landfill (D5525), aerobic microbial activity (D5247) and marine floating conditions (D5437).

A second group of ASTM standards is aimed at the study of CO_2 generation in aerobic environments; including the use of sludge (D5209), activated sludge (D5271) and controlled composting conditions (D5338).

A third group of ASTM standards approaches the evolution of CH_4 and CO_2 in anaerobic environments (D5210), anaerobic biodegradation (D5511) and accelerated landfill (D5526). The ASTM D6400 establishes the requirements to distinguish between degradable and biodegradable plastics.

Finally, ASTM D6954 (4) is recommended to be applied only for the study of polymeric materials commercially known as oxo-biodegradables. It is subdivide into three parts:

1. The sample should be exposed to temperatures between 20 and 70°C in the presence of specific air or humidity levels. For thin films, the period of exposition should be the time required to achieve 5% elongation at break or less and an average molecular weight (Mw) of 5000 or less units, measured at three different temperatures.
2. After the samples are exposed to an abiotic degradation process, the test material should be submitted to degradation in appropriate environments (D5988, D5338- referenced to the ISO 14855- and D5526). The time profile is recorded in the carbon dioxide evolution.

3. Toxicity tests are made, which involve considerations of ecological impacts in the final disposal (D5951- referred to by OECD 208).

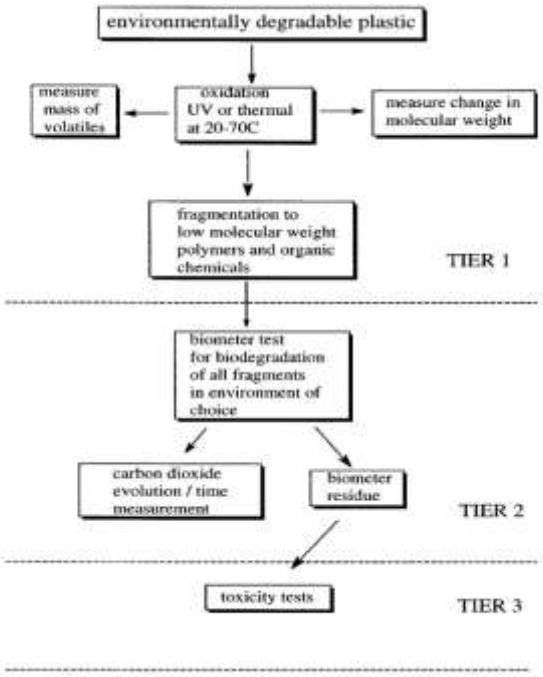

Figure 1. Flow schematic of the Guide ASTM D6954.

5.2 International Standards Research (ISR)

The behavior of biodegradable plastics in composting facilities and laboratory conditions has been studied by the International Standards Research (ISR). ISR has determined three criterias that plastics have to meet to be compostable:

- They must degrade at the same rate that the compostable material and do not leave toxic or persistent residues.
- It must disintegrate during the active composting. For that reason, it cannot be found visible or evident fragments on the screens.
- They must not have any ecotoxicity or phytotoxicity which can affect the compost capacity to let plants grow.

5.3 International Standards Organization (ISO)

Three standards of the International Organization for Standardization (ISO) have established the criterias by which European biodegradable plastics are currently evaluated.

- ISO 14855 (aerobic biodegradation under controlled conditions);
- ISO 14852 (aerobic biodegradation in aqueous mediums); and
- ISO 15985 (anaerobic biodegradation under high-solids anaerobic-digestion conditions).

ISO 14855 is a test of controlled aerobic composting; ISO 14851 and ISO 14852 are tests of biodegradation specially designed for polymeric materials.

An important part of biodegradable plastics evaluation is to determine the disintegration in the final product form. A controlled pilot scale test or a large scale aerobic composting treatment center can be used. Due to the nature and conditions of such disintegration tests, they cannot differentiate between biodegradation and abiotic disintegration, but instead it is shown that enough disintegration has been achieved in the test materials during the specified test time.

5.4 European Committee for Normalization (CEN)

In 1999, the European Committee for Normalization (CEN) established the standard prEN 13432. This standard provides the Europe Directive of the European Commission on packaging and packaging waste with appropriate technical regulations. It is a point of reference to all European producers, authorities, installation administrators and consumers. The standard specifies requirements and procedures for determining the compostability of plastic materials for packaging based on four main areas:

- Biodegradability;
- Disintegration during the biological treatment;
- Effect in the process of biological treatment; and
- Effect on the quality of resulting compost.

A packaging material intended to enter the bio-waste sequence must be recognized as biodegradable or compostable by the final user. The strictest European standard for biodegradability is CEN 13432. This standard may apply to others packaging materials in addition to polymers and incorporates the following tests and standards:

• ISO 14855 (Determination of the ultimate aerobic biodegradability and disintegration under controlled composting conditions- Method by analysis of evolved carbon dioxide);
• ISO 15985 (Plastics -- Determination of the ultimate anaerobic biodegradation and disintegration under high-solids anaerobic-digestion conditions -- Method by analysis of released biogas);
• ASTM D5338 (Standard Test Method for Determining Aerobic Biodegradation of Plastic Materials under Controlled Composting Conditions);
• OECD 208 (OECD Guidelines for Testing of chemicals 208: Terrestrial Plants, Growth Test; Organization for Economic Co-operation and Development, 2 rue André Pascal, F - 75775 Paris).

To approve a material by the standard, it must not stay more than 6 months in any of the test stipulated conditions mentioned above and it must have an approval level of 90%. Further, the material must not exceed a content of heavy metals above 50% for "normal" compost.

It is recommended to apply the standard CEN 13432, due to its wide range in the study of polymeric materials commercially known as compostables.

6 Bibliography

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