TECHNICAL BULLETIN: PE RECYCLING AND BIODEGRADABILITY

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1 Introduction

Biodegradability and recycling are two topics currently in development and are the subject of numerous research projects which are generating an evolution in the plastic industry.

The recently environmental regulations and the growth of world concern about the correct disposal of plastic waste have motivated big investments by companies to develop biodegradable polymers and to obtain a more efficient disposal of the plastic waste.

2 Biodegradability

There are biodegradable polymers derived entirely from biological sources such as corn, wood pulp, etc., or may be synthesized by bacterias of small molecules such as Butyric Acid or Valeric Acid. There are also polymers derived from petroleum (e.g. aliphatic polyester or aliphatic-aromatic co-polyester) and mixed sources from oil and biomass. (1)

The disadvantages of biodegradable polymers are: high cost and poor properties - in some aspects - such as: fragility, low heat distortion temperature, high gas permeability, low melt viscosity for processing, etc. This restricts, in a broad range, the applications in which they can be used. For this reason, it has been invested large amount of economic resources in researches devoted to achieve biodegradation of polyolefins such as polyethylene, which is one of the most used in applications where biodegradable polymers have great limitations (e.g. packaging).

Among the most important investigations in order to degrade polyethylene (PE), there are two areas that are currently under development with promising preliminary results:

- PE blends with biodegradable materials (such as starches).
- Use of additives to degrade the polymer.

a) PE blends with biodegradable materials.

Several blends of PE have been tested with other biodegradable polymers such as starch from potatoes or cassava (in amount of 5 to 50%), Polyhydroxybutyric (PHB), Polyhydroxyivalere (PHV) and poly (vinyl alcohol) (PVA).

The main disadvantage in these blends is the poor adhesion observed between the phases, which affects and decreases their final mechanical properties. Thus, nowadays it is investigating the effect of different types of compatibilizers between these mixtures.

Studies of the compatibilizers between PE and starches have been made by V. Balsamo et al. (2) and R. H. Mendoza et al. (3); between HDPE and PVA by R. Brandalise et al. (4) and between PE and PHB blends have been studied by S. Martell (5).

In general, it has been found techniques and compatibilizers which achieve higher blend properties than each individual component (synergism).

In order to degrade these mixtures of PE, it has been organized experiments burying the samples in a medium that promote the degradation as organic solid wastes commonly found in any garden (4).

b) Additives that degrade the polymer

The use of totally degradable materials that can replace the PE is theoretically feasible, but due to the PE worldwide high consumption, it could be necessary a significant investment of resources to achieve this goal.

By contrast, many companies have decided to invest in the development of technologies that allow obtaining degradable PE. One of the techniques is to add additives that promote the polymer degradation after being used it. In this regard, additives that are thermal and / or UV degradable have been developed and also some called "oxo-degradables".

Amongst the companies that have developed additives and / or use additives in manufacturing applications of PE are:

- EcoSafe®. www.ecosafeplastics.com: Produce oxo-degradable and biodegradable plastic packaging. (6)

- Willow Ridge Plastics, Inc. www.biodegradableplastics.net: Produce additives based on corn starch (biodegradable) with pro-degrading ingredients which use UV and oxidative methods of activation. They also produce other additive packages that make the PE-oxo-biodegradable and UV degradable. (7)

- ECM Biofilms. www.ecmbiofilms.com: this company produces a set of additives that are biodegradable and not exclusively UV-degradable, i.e., the degradation process can occur only if the material receives sunlight, which indicates that this material will degrade due to bioactive compounds which attract colonies of microorganisms that metabolize and neutralize the polymer. (8)

- TDPA™ additives. www.epi-global.com: The degradation occurs due to the reaction of plastics with the oxygen from air (oxo-degradation), also initiated by exposure to the ultraviolet rays (UV-degradable), high temperatures and / or mechanical stress. This company declares that their products manufactured with PE (shopping and supermarket bags) have shown to biodegrade to non-toxic materials over a period of time ranging from a few months to several years, depending on the additive formulation. (9)

- Addiflex® additives. www.greenclubinc.com: they guarantee to produce the material oxo-degradation up to 90%. (10)

- D_2W® additives. www.degradable.net: presents a package of additives which activate the polyethylene oxo-degradation after a preselected period of time. These additives are included during extrusion process. (11)

Metals are often used to start the material oxidation. That's why some ecological groups state that these additives can generate toxic waste, in addition to the problem that some kind of additives, such as those activated by UV and temperature, which not degrade in media with absence of these factors, such as buried bags and parts submerged in deep water.

These additives can be prepared to degrade the polymer at a time of:

- 3 to 6 weeks in special preparations to be buried.
- 3 to 5 years if it is left on sites such as landfills.
- 5 to 10 years to be biodegraded.

3 Recycled polyethylene

There are mainly two ways to recycle plastics: mechanical and chemical recycling.

a) Mechanical Recycling

The mechanical recycling consists in the reuse of the product, which involves grinding again and melting the plastic already used to re-mold it in a new form or application. Plastics must be sorted and separated by type (material) before they can perform mechanical recycling. Technologies to introduce the automatic classification of different types of plastics are currently in development.

Fluorescent identifiers

It is the optical identification of the types of plastics through fluorescent identifiers incorporated into the material in small concentrations previous to the product manufacture. (12)

Infrared spectroscopy

The technique of infrared spectroscopy has allowed the development of several studies to increase efficiency and speed in the identification, classification and separation of plastics. A research done by Scott, D.M. (13) includes a device to automatically identify and separate the plastic waste through an identifier which uses a two-colour filter in a near-infrared spectrometer.

PIM recycling process

The Environmental Recycling Technology plc company (ERT plc http://ertplc.com) has developed a process where blended plastics, and even with some contaminants such as sand and paper, can be molten and ground in small grains which can be used in the manufacture of new pieces as part of the piece core and even the surface. (14)

This mixture of materials has been shown to possess good mechanical properties, thermal and sound insulation, as well as being lightweight.

b) Chemical Recycled

It breaks the polymer chains into their constituent monomers, which will then be able to re-use in refineries, petrochemical and chemical production.

Pyrolysis

It is a process where waste is heated in the absence of oxygen in a closed-down enclosure to decompose them into their basic components.

Studies performed by NREL (National Renewable Energy Laboratory - USA) (15) have developed pyrolysis processes which can decompose certain types of wastes into the monomers that compose them, thus allowing to use these components in the manufacture of new polymers. The advantage of this technique is that the wastes are not required to be classified or separated before being processed.

Another work in this area has been developed by Buzeta Frabicio et al. (16), who used a fluidized bed reactor where a mixture of HDPE, LDPE and PP could be broken down into compounds such as methane, ethane and propane in gas phase, and benzene and toluene in liquid phase.

Gasification

This technique generates gas that can be used to produce chemicals such as hydrogen, methanol and ammonia. In a first low temperature stage, sand is heated to 600 - 800 °C within a gasification cavity, later the plastics are introduced into the container where they decompose, and then, when they come into contact with the sand, form hydrocarbons, carbon monoxide and hydrogen. This gas mixture passes to a second stage of high temperature (between 1300 and 1500 °C) where they mix and react with water vapor to produce mainly carbon monoxide and hydrogen. At the reactor exit, the gas is cooled quickly to prevent the formation of dioxins.

Recent investigations have developed techniques to gasify blends of wood and PE; one of these researches was developed by Johannes van Kasteren (17) which could achieve optimum conditions for the gasification process.

Use of waste as alternative fuel

There is a discussion about using plastic waste as fuel or in power generation processes. Incinerating plastic waste is one of the most polluting and harmful processes to the environment, but in order to reduce their impact, it has also been used as a means for power generation.

On the other hand, techniques and plants that are responsible for producing fuels from plastic wastes have been developed, e.g. RPF (Refused Paper and Plastic Fuel). Several Japanese companies have been dedicated to the development of RPF and have establish the Japan RPF Association, constituted by eight companies and nine plants, among which are Shinsho Corporation(http://www.shinsho.co.jp/english/tekko-genryo.html) & Sekishouten C.., Ltd. (http://www.sekishouten.jp) who promoted the creation of this association and are the plants with the longest use of these technologies.

It have been invested a lot of resources in Japan to reduce petroleum imports and encourage the use of renewable energy and waste. This type of energy has the additional advantage of reducing the amount of CO_2 into the atmosphere.

There are other companies such as Amandus Kahl GmbH & Co. KG (Germany: http://www.amandus-kahl-group.de/index.php?set_lang=en), which are also responsible for producing this type of fuel waste.

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