Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 1, Number 9; October, 2014 pp. 89-92

http://www.krishisanskriti.org/jbaer.html

Biodegradable Polymers - An Overview of their Applications

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Abstract: **Polymers are formed from hydrocarbons, hydrocarbon derivatives or sometimes from silicon. They are made of many parts. Polymer is made of two words i.e. Poly means many and Mer means parts. There is increasing concern today about the preservation of our ecological systems. Biodegradable polymers bring a significant contribution to the sustainable development in view of the wider range of disposal options with minor environmental impact. Polymer degradation is a change in the properties i.e. tensile strength, color and shape of a polymer or polymer based product under the influence of one or more environmental factors such as heat, light or chemicals**

Biodegradable means capable of undergoing decomposition into carbon dioxide, methane, water, inorganic compounds and biomass. Biodegradable polymers derived from renewable resources are broadly classified as polymers directly extracted/removed from natural materials, polymers produced by microorganisms or genetically transformed bacteria, polymers produced by chemical synthesis from renewable bio - derived monomers. The biodegradable polymers are used in medical, agricultural and packaging areas. Using biodegradable polymers in many fields of industry, instead of synthetic materials, may significantly help to protect the natural environment.

Keywords: **Biodegradable Polymers, Macro Molecules, Medical, Agriculture, Packaging.**

1. INTRODUCTION

Polymers have become an important part of our daily living. They are so much around us that at every step we encounter one or the other polymer. They are formed from hydrocarbons, hydrocarbon derivatives or sometimes from silicon. They are made of many parts. Polymer is made of two words i.e. **Poly** means many and **Mer** means parts. When a molecule is used to produce a polymer, it is called monomer - mono meaning single.

The monomers are small building-block molecules. So a polymer is a substance made of many parts and a monomer is just a single part of a polymer. **Polymers** are the giant molecules of chemistry. Chemists also call them **macro-molecules**. Synthetic polymers are important part of modern life, but nature also makes polymers, they are found in all living matter.

There is increasing concern today about the preservation of our ecological systems. Persistent polymers generate significant sources of environmental pollution, harming wildlife when they are dispersed in nature. As they represent a large part of the waste collection at the local, regional and national levels, institutions are now aware of the significant savings that compostable or biodegradable materials would generate.

The potential of biodegradable polymers has been recognized for a long time since these can overcome the limitation of the petrochemical resources in the future. The fossil fuel and gas can be partially replaced by green agricultural resources which will also help in the reduction of carbon dioxide emissions. However, till now, biodegradable polymers have not found extensive applications in industries to largely replace conventional plastic materials, reasons being their high production costs and sometimes their underperformed properties. These polymers bring a significant contribution to the sustainable development in view of the wider range of disposal options with minor environmental impact. As a result, the market of these environmentally friendly materials is in rapid expansion, 10–20 per cent per year **(Narayana 2001)**.

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Sustainability is defined as the development which meets the needs of the present time without compromising the ability of future generations to meet their own needs. According to **Narayan (2001)**, the manufactured products must be designed and engineered from **conception to reincarnation**, the so-called **cradle-to-grave approach**.

2. MEANING AND CLASSIFICATION OF BIODEGRADABLE POLYMERS

Polymer degradation is a change in the properties i.e. tensile strength, color and shape of a polymer or polymer based product under the influence of one or more environmental factors such as heat, light or chemicals **(Bismarc *et al* 2002)**. Biodegradable means capable of undergoing decomposition into carbon dioxide, methane, water, inorganic compounds and biomass. Biodegradable polymers offer important contributions by reducing the dependence on fossil fuels and through the related positive environmental impacts such as reduced carbon dioxide emissions. Biodegradable polymers derived from renewable resources are broadly classified according to the following three main categories:

i. ***Polymers Directly Extracted/Removed from Natural Materials***

ii. ***Polymers Produced by Microorganisms or Genetically Transformed Bacteria***

iii. ***Polymers Produced by Chemical Synthesis from Renewable Bio-derived Monomers***

a. ***Polymers Directly Extracted/Removed from Natural Materials:*** These polymers are by nature hydrophilic and somewhat crystalline. These are obtained from agricultural or forest plants and trees. **These polymers are as follows:**

- **Starch**: It is extracted from various types of cereals e.g. wheat, rice, corn and from tubers e.g. potatoes. It is stored in seeds or roots of the plant material representing their main energy reserve.
- **Cellulose:** It is present in cell walls of all plants. Cellulose is a complex polysaccharide. Cellulose differs from starch where glucose units are linked by β-1, 4-glycosidic bonds whereas the bonds in starch are predominantly α-1,4 linkages. Cellulose is a hard polymer and has a high tensile strength and elongation of 4 per cent (**Bisanda and Ansell 1992, Eichhorn *et al* 2001**). In order to overcome the inherent processing problems of cellulose, it is necessary to modify, plasticize, and blend with other polymers.
- **Proteins:** The word **Protein** has been derived from the Greek word **Proteios** which means first, foremost and primary. The proteins are important renewable resources produced by animals, plants and bacteria. Majority of the proteins are comprised of linear polymers built from a series of up to 20 different amino acids. All proteins are specific co-polymers with regular arrangements of different kinds of α - amino acids; protein biosynthesis is thus an extremely complex process demanding many enzymes of different types. Proteins can be processed with the same kinds of approaches developed for starch-based materials Proteins can be classified according to the shape and solubility as fibrous, globular, or membrane. Fibrous proteins tend to have relatively simple, regular linear structures. Globular proteins are roughly spherical **(Zhang and Zeng 2008)**.
- **Soybean Proteins:** Soybean proteins are the isolated proteins from soybean. Soybean proteins have 38–42 per cent crude protein, 16–20 per cent triglycerides and around 33 % carbohydrates in dry form.
- **Corn Proteins:** Corn proteins comprise 9 per cent of the dry weight of corns. Zein (Soluble in alcohols and highly hydrophobic), glutelin (Soluble in aqueous alkaline solutions), albumins and globulins are different types of corn proteins. .
- **Wheat Gluten:** Wheat gluten has equivalent quantities of gliadins and glutenins which have comparable amino acid compositions, with high concentrations in glutamine and proline. The amount, size distribution and macromolecular architecture of glutenins and gliadins greatly influence processing, mechanical and physicochemical properties of the gluten (**Domenek *et al* 2004**).

- **Gelatin:** Gelatin is an animal protein. It is comprised of 19 amino acids joined by peptide linkages. It is extracted from collagen which is mostly found in fibrous tissues such as skin, tendons and ligaments. It is also found in bone, cartilage, cornea, blood vessels, intervertebral disc and gut. Gelatin is commonly used for biomedical applications due to its biodegradability and biocompatibility in physiological environments, in contact with living tissues **(Ofokansi *et al* 2010).**
- **Caseins:** Caseins are present in mammalian milk, making up 80 per cent of the proteins in cow milk and between 60 and 65 per cent of the proteins in human milk. Caseins have been found to be useful in adhesives, controlled releases and biomedical applications.

b. ***Polymers Produced by Microorganisms or Genetically Transformed Bacteria:*** These polymers are as follows:

- **Polyhydroxyalkanoates (PHAs):** PHAs can be formulated by bacterial fermentation, isolation and purification from fermentation using several renewable waste feedstocks. PHAs are present naturally in a variety of organisms, but microorganisms can be employed to tailor their production in cells. More than 150 PHA monomers have been identified as the constituents of PHAs. Such diversity allows the production of bio-based polymers with a wide range of properties, tailored for specific applications **(Steinbüchel and Valentin1995)**. PHAs have wide range of applications in packaging, agriculture, medicine and biomedical areas.

c. ***Polymers Produced by Chemical Synthesis from Renewable Bio – derived Monomers:*** The polymer under this category is as follows:

- **Polylactic Acid (PLA):** PLA can be formulated from lactic acid by direct poly condensation reaction or ring-opening polymerization of lactide monomer. It has many distinct characteristics e.g. high rigidity, good transparency, glossy appearance and ability to tolerate various types of processing conditions. PLA is widely used in many day-to-day applications. It has been mainly used in food packaging (food trays, tableware such as plates and cutlery, water bottles, candy wraps and cups).

3. APPLICATIONS OF BIODEGRADABLE POLYMERS

The biodegradable polymers are used in following three main areas with more rapidly developed medical applications:

i. ***Medical Application***

ii. ***Agricultural Application***

iii. ***Packaging Application***

a. ***Medical Application*****:** The biodegradable polymers are being used in following medical related areas:

- **Bone - Fixation Devices:** Biodegradable polymers are used in bone- fixation devices. These adapt to the dynamic processes of bone healing through decreasing amounts of weight - bearing material. Over a few months the introduced material disappears and there is no need to operate on a patient to remove it. Biodegradable implants offer clear advantages over the traditional metal implants. They retain their strength long enough to support a healing bone, then gradually and harmlessly disintegrate in the patient's body **(Gourville 2005).** These provide the correct amount of strength when necessary and harmlessly degrades over time, until the load can be safely transferred to the healed bone. There is no risk of metal allergic reactions. Moreover there is increased patient satisfaction.
- **Adhesion Prevention:** Biodegradable polymers provide flexible and tough cover over the traumatized soft tissue. Post-operation tissue adhesion can occasionally cause serious complications.
- **Vascular Grafts:** Vascular grafts made of biodegradable polymers are widely used.
- **Surgical Sutures:** Sutures made from PLA and their co-polymers are most commonly used. They maintain the structural integrity and help in proper healing of wounds.

b. ***Agricultural Applications***

The use of biodegradable polymers in agriculture has developed at a great rate. The biodegradable polymers are being used in following agriculture related areas:

- **Controlled Release of Agricultural Chemicals:** Biodegradable polymers are mainly used to control the delivery rates, mobilities and periods of effectiveness of the chemicals for agriculture purposes.
- **Agricultural Mulches:** Mulches made of biodegradable polymers are commonly used to reduce weeds, to maintain constant moisture level and to increase soil temperature, improving the plant growth rate.

c. ***Packaging Applications***

Starch, cellulose and PLA based polymers are commonly used for packaging.

4. CONCLUSIONS

Fossil fuels are decreasing day by day and for sustainable development, we should show great interest in developing biodegradable products. Our government must endorse the widespread application of biodegradable products especially packaging materials in order to reduce the volume of inert materials currently being disposed in landfills, occupying scarce available space.

- Government should reduce taxes for sustainable biodegradable products. Government should also encourage public authorities to give preference to bio-based products in procurement.
- Government should begin a reflection process with stakeholders on biodegradable product labels and information for consumers.
- In the end it can be said that using biodegradable polymers in many fields of industry, instead of synthetic materials, may significantly help to protect the natural environment.

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