EDP

Table of Contents

EDP

ICS-UNIDO is supported by the Italian Ministry of Foreign Affairs

Pure and Applied Chemistry
International Centre for Science and High Technology
ICS–UNIDO, AREA Science Park
Padriciano 99, 34012 Trieste, Italy
Tel.: +39-040-9228110 Fax: +39-040-9228115
www.ics.trieste.it

Acknowledgements

We wish to thank Mr. Andrej Krzan (ICS-UNIDO expert in the Subprogramme on EDP) for his substantial contribution to the preparation of this publication. Inputs and suggestions which were given by other experts in the field (Mr. Emo Chiellini, Mr. Ramani Narayan, Mr. Graham Swift, Mr. Yoshiharu Doi, Mr. Fred Edgecombe, Mr. Ingo Sartorius and Mr. Michel Vert) are also highly appreciated.

Contact details

For further information, please contact:

International Centre for Science and High Technology ICS-UNIDO
Area of Pure and Applied Chemistry
AREA Science Park
Padriciano 99
34012 Trieste, Italy

Area Director: Stanislav Miertus

Tel: (00 39 040) 9228 114/110/116
Fax: (00 39 040) 9228 115
E-mail: stanislav.miertus@ics.trieste.it
Web-site: http: //www.ics.trieste.it

EDP

Preface

The present *Brief Guidelines on Environmentally Degradable Plastics* (EDP) were prepared by the **International Centre for Science and High Technology** of the **United Nations Industrial Development Organization** (ICS-UNIDO) with the purpose of offering up-to-date information on the rapidly developing area of environmentally degradable plastics to key decision makers in governmental, non-governmental, technical, educational and other positions around the globe.

Significant growth in the use of plastic materials has brought about the realization that current plastics production from non-renewable fossil resources and the current waste management practices are not sustainable and will result in adverse consequences in the future. Waste management options that allow waste plastics to remain in the natural carbon cycle together with the use of renewable resource feedstocks are the key drivers for the use of environmentally degradable plastics that promise to alleviate these problems. They are expected to play an important role in achieving higher sustainability in the production, use and disposal of plastics in the future. Through the promotion of international projects and awareness building among decision makers ICS-UNIDO wishes to promote consideration and inclusion of EDP in the future development of activities connected to plastics with the goal of reaching higher levels of global sustainability.

The first part of this booklet is focused on the technical and technological concepts of EDP and does not require specialized technical knowledge. The second part is a brief introduction to UNIDO and ICS-UNIDO with particular attention given to activities related to EDP. Special care has been taken to provide as concise a format as possible and still allow a full presentation of the topic.

EDP

EDP subprogramme events 2001 - 2003:

- Workshop: *Position of EDP in plastic waste management*, Lodz,. Poland, July 2001
- International Meeting: *Recycling and EDP from renewable resources*, Jakarta, Indonesia, September 2001
- Workshop: *Sustainable polymers: Promotion of EDP concept in Middle East and Gulf countries*, Bahrain, November 2001
- Expert Group Meeting: *Environmentally degradable plastics and sustainable development*, Trieste, Italy, December 2001
- Expert Group Meeting: *Environmentally degradable plastics: State-of-the-art and outlook*, Trieste, Italy, September 2002
- Workshop: *Plastics recycling and development of EDP*, Bangkok, Thailand, October 2002
- Workshop: *Sustainable development and EDPs*, Beijing, China, October 2002
- Workshop: *EDP, plastics recycling and polymer waste management*, Concepcion, Chile, November 2002

For the year 2003, the ICS-UNIDO work programme includes a series of awareness building events focused on the promotion of relevant projects in Uganda and Iran and an expert group meeting to be held in Trieste.

Publications resulting from projects and events carried out within the EDP subprogramme:

- ICS-UNIDO International Workshop on Environmentally Degradable Polymers, December 1997, *NAM Ss&t Newsletter*, Jan/Mar 1988.
- Proceedings from ICS-UNIDO sponsored international workshops, meetings and expert group meetings
- *ICS-UNIDO Survey of Trends in Environmentally Degradable Plastics*, web-based national reports
- *Information Package on Environmentally Degradable Plastics* Project: Managers of Innovation in Environmentally Degradable Plastics (funded by the European Commission, Leonardo da Vinci programme (also on CD-ROM), June 2001.

for world-wide recognition and appreciation at the Green Olympic Games to be held in Beijing, China, in 2008.

- *Sustainable polymeric materials and environmentally degradable plastics from renewable resources*

Beneficiary region: Indonesia (also applicable to other South East Asian countries).
The project aims to overcome the issues connected to plastic waste by specific actions: Preparation of a waste management support software tool comprising guidelines for decision makers involved in waste management; assessment of the best technologies available for the production of environmentally degradable polymeric materials from renewable resources with selection of the best suited to the Indonesian situation and hence applicable also to countries in South East Asia; assessment of the most efficient ways to promote technology transfer for production and manufacturing of EDP; the transfer will initially be designed on a pilot basis and in a later phase (beyond the present project) will be followed by transfer on an industrial scale (production line with an annual capacity of 4000 tonnes).

- *Plastic waste management and environmentally degradable plastics from renewable resources*

Beneficiary region: Uganda (also applicable to other Central/East African countries).
The project will focus on waste related problems connected to the rapid increase in the use of plastics in Central and East African countries and Uganda. It aims to overcome issues connected to plastic waste through specific actions. Attentiion will be given to an analysis of plastic waste and the identification of the most suitable recovery and reuse technologies and schemes for the region. The result will be a plastics recycling plant and the introduction of local SMEs into the recycling and recovery business. The second step of improving environmental performance of plastics will be dedicated to the evaluation of opportunities for the production and use of EDP as alternatives for certain uses of conventional non-degradable plastics. The EDP option is particularly interesting in connection to the strong agricultural sector. Long-term regional capacity will be supported by the establishment of a regional centre of competence for sustainable plastics use.which will act as a national reference laboratory for plastics recycling and EDP with an outreach throughout the East/Central African region.

Two other project concepts are being elaborated in cooperation with Thailand (on the development of EDP from renewable resources and with Chile (on the promotion of industrial applications of EDP in Latin American countries).

Opportunities in Plastics and EDP

Development in the second half of the 20th century was strongly characterized by the emergence of polymeric materials and plastics that have permeated virtually every material basis of human existence and activity. It can be safely claimed that plastics represent one of the foundations for the current level of development, health and living standards of people around the world. This remarkable success is expected to continue into the 21st century when demand for plastics should undergo a 2 to 3 fold increase. The majority of this growth will result from increases in plastics consumption in developing countries where annual per capita consumption is currently between 1 and 15 kg, compared to approximately 100 kg in industrialized countries.

The explosive growth of plastics consumption has lead to the realization that environmentally sustainable plastic production and waste management are needed. A number of disposal, recycling and reuse technologies have been developed to cope with the problem of plastic waste but none are without weaknesses. *Environmentally degradable plastics* (EDP) open an additional waste management option in which composting plays a major role. The degradability of these materials after use allows plastics to remain in the natural carbon cycle. EDP with the option of composting as the waste management method are poised to replace conventional commodity plastics in those segments where recycling is difficult and labour-intensive, and results in a low cost-performance of recycled materials. The continued shift of plastics production from non-renewable resources (*e.g.* oil) to renewable resources will further contribute to higher sustainability. EDP made on the basis of renewable resources should be neutral in terms of carbon dioxide emissions and will help in dealing with global environmental issues such as greenhouse gas emissions and global warming. Waste management and renewable resources use are the key drivers in EDP use and development.

The increase in scientific and industrial interest in EDP can be seen in the rapid growth of the number of literature references and patents. This wealth of research and development work has yet to be translated into industrial output of EDP but experiences from past technological breakthroughs suggest a period of rapid growth in EDP use.

What are EDP?

Environmentally degradable plastics (EDP) are a wide group of natural and synthetic polymeric materials that undergo chemical change under the influence of environmental factors. The chemical change must be followed by complete microbial assimilation of degradation products resulting in carbon dioxide and water. The degradation and assimilation must occur at a sufficiently rapid rate so as to avoid accumulation of materials in the environment.

EDP can be based on renewable or non-renewable feedstocks.
Examples of EDP from renewable feedstocks:
cellulose, starch, starch esters, collagen, viscose, cellulose acetate (DS<2), polyhydroxy alkanoates, polylactic acid…
Examples of EDP from non-renewable feedstocks:
polyvinyl alcohol, polycaprolactone, aliphatic-aromatic copolyesters, blends of starch and biodegradable polyesters…

Renewable feedstocks used for EDP production can be simple natural compounds (such as amino acids or sugars) or can be derivatives of natural compounds that have undergone chemical transformation to give an appropriate building block for EDP (lactic acid made by fermentation of sugars obtained from corn starch). Natural polymers (e.g. starch, collagen, chitin, cellulose etc.) can form the building blocks for EDP. In nature polymers are produced by plants, animals and microorganisms. The most abundant natural polymers are polysaccharides and proteins which together represent some of the most diverse and complex natural substances. Although it is generally believed that natural substances can be degraded by natural processes this is not always so. Some natural polymeric compounds can be quite resistant to biodegradation and their degradation rates are insufficient to qualify the materials as EDP. Such is the case with lignin and certain types of wood which are used outdoors thanks to their high resistance to the environment. Natural polymers can also be chemically modified to make them more easily processable. EDP from modified natural polymers include viscose, cellulose acetate, and chitosan. However, chemical modification may lead to a loss of biodegradability, since specific enzymes cannot recognize the new substrate. The use of renewable feedstocks does not deplete limited sources and given that the production is not wasteful it can lead to higher sustainability.

EDP related activities at ICS-UNIDO

Main ongoing and recently completed projects in the field of EDP:

- *Management of Innovation in Environmentally Degradable Plastics*

This project, completed in 2001, was funded by the European Commission within the framework of the Leonardo da Vinci Programme. It produced an information package, a training package and a database on EDP technologies, relevant regulations, standards and waste management issues.

- *Sustainable polymeric materials development based on environmentally degradable polymeric foams in Korea and East Asian countries for production of lunch boxes*

Beneficiary region: Korea (also applicable to other East Asian countries, such as China and Thailand).
The project proposal stems from the growing concern about plastic waste pollution deriving from the high consumption of lunch boxes made of polystyrene foam, whose mechanical recycling is not economically viable.
Laws have been passed in Korea and China banning the use of lunch boxes made from expanded polystyrene, however suitable replacements are lacking. The project aims to develop new foamable formulations, based on EDP materials possibly combining natural fillers from the agro-industry, suitable for the production of lunch boxes. The creation of awareness and capacity-building through training and networking of institutions involved as well as know-how and technology transfer constitute the ultimate goal of the project.

- *Environmentally degradable packaging and consumer products for the Olympic Games*

Beneficiary region: China (also applicable to other East Asian countries).
The project addresses the growing concern about plastic waste pollution caused by packaging and consumer products based on biostable plastics whose recycling is not economically viable. Laws have already been passed in China and other Asian countries banning the use of consumer products that have been identified as the major cause of so-called 'white pollution'. There is considerable pressure to find solutions to this issue by various government ministries as well as a specialized committee for the development of EDP products for specific use at the 2008 Beijing Olympic Games.
The Green Olympic Games will be used as an effective promotion of the new sustainable polymeric materials. The project is aimed at the identification of EDP suited to the development of blends and composites with natural EDP and fillers from renewable resources. These will be converted to packaging and consumer products, suited for biorecycling under controlled conditions. Products from developed EDP will find their forum

Area of Pure and Applied Chemistry and its Subprogramme on EDP

The following subprogrammes are currently being developed within the area of *Pure and Applied Chemistry*, which has recently been specifically focusing on Sustainable Industrial Chemistry.

Catalysis and Sustainable Chemistry: Catalysis has a major role in the development of clean chemical processes, which translates into better yields and fewer, less polluting by-products.
Remediation Technologies: Many contaminated sites need to be cleaned-up. Remediation techniques include degradation of pollutants into safe by-products.
Combinatorial Chemistry and Technologies: In the pharma, agro and chemical industries, combinatorial chemistry used along with molecular modelling is aiding the discovery of new compounds and raising efficiency in relevant industries.
Environmentally Degradable Plastics EDP: Biodegradable plastics can alleviate disposal problems. ICS evaluates industrial processes for the production of these materials, with the focus on an integrated approach to EDP promotion both for industrial production and targeted use.

EDP is one of the programmes carried out by ICS-UNIDO. The programme aims at taking up-to-date information and know-how directly to developing countries and stimulating the diffusion of harmonic decision-making regarding the global issue of plastic waste to the benefit of these countries. Actions undertaken in the EDP Subprogramme are focused on project proposal preparation and promotion, complemented with the organization of workshops and expert group meetings and development of in-house expertise.

EDP

EDP can also be produced from **non-renewable feedstocks**, most commonly from natural oil and gas. The renewable and non renewable sources are often indistinguishable when looking at the final EDP. It is possible to prepare important feedstock chemicals from either source. A number of EDP depend on feedstocks from both sources and the concept of an '**environmental footprint**' was thus developed as a measure of the environmental impact of a material.

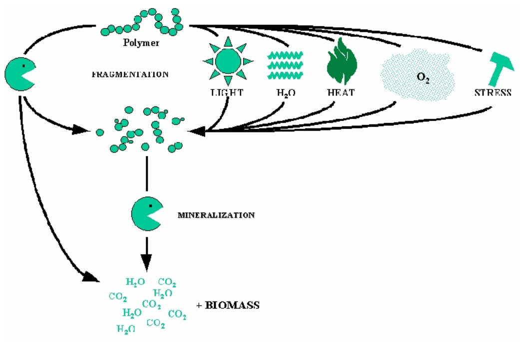
EDP are often used as blends or composites in which two or more biodegradable materials are combined to provide optimal performance while maintaining or enhancing complete biodegradability. The most common application of this type is the use of starch as an additive in biodegradable films and can also include the use of natural fibres (straw, flax etc.) as reinforcement in biodegradable polymer matrices. For true EDP it is important that all components of a blend or composite degrade and are microbially assimilated at acceptable rates.

Regardless of feedstock source an EDP material must have the following properties:

- Rapid degradation and/or biodegradation
- Bioassimable degradation products (leading to CO_2 and water via biological pathways)
- Ease of processing
- High versatility
- Acceptable performance
- An acceptable price for intended use

Degradation

Degradability is a key property of EDP. Degradation can be described as an irreversible process leading to a significant change in the structure of the material, typically characterized by a change in properties (e.g. integrity, molecular weight or structure, mechanical strength) and/or fragmentation. The degradation of EDP is caused by environmental conditions and living organisms. For practical purposes, EDP degradation must be complete, i.e. lead to the evolution of CO_2, H_2O and other bioassimable products, within a prescribed period.



Pathways of polymer degradation

Mechanisms of degradation
Polymers degrade depending on the nature of the polymer and on the environmental conditions which may vary from exposure to abiotic factors to insertion into a living organism. Complete degradation is reached in two steps.

Step 1: *Fragmentation*

In the first stage of degradation EDP are degraded into sufficiently small particles for use by microorganisms as nutrients. This step is called fragmentation and will lead to the visual disappearance of the plastic. The process must yield products of a molecular size up to 1000 Dalton (for example: a chain of 6 glucose molecules.

EDP

ICS-UNIDO

The International Centre for Science and High Technology of the United Nations Industrial Development Organization (ICS-UNIDO) was established in 1988, to act as a focus for transfer of sustainable advanced technologies to developing and emerging-economy countries, through awareness and capacity building and promotion of multilateral projects. UNIDO is a specialized agency of the United Nations dedicated to promoting sustainable industrial development in developing and transition-economy countries. It harnesses the joint forces of government and the private sector to foster competitive industrial production and international industrial partnership and promote socially equitable and environmentally friendly industrial development.

The technology transfer at the heart of the ICS mandate is realized through long-term international and regional projects with partner institutions in beneficiary countries. Training courses, workshops, meetings, fellowships, act as the basis for formulating project proposals that are submitted for donor funding. Each year ICS promotes a series of projects, offers approximately 20 fellowships and organizes about 50 training events, involving more than 1000 experts and technologists. Integrated information systems and advisory services are being developed at ICS to support the technology transfer effort. Elements include databases (such as best available technologies), expert systems, techniques in assessment software, mathematical modelling, molecular design, and process simulation. Examples of application areas are industrial siting, drug design and design of new materials.

The Italian Government makes an annual contribution to ICS through UNIDO. Other governments and public and private bodies may participate in ICS funding. While ICS provides seed money for formulation effort and feasibility studies, additional resources to finance projects launched by partner institutions in beneficiary countries are sought through international fund raising. The ICS programme is formulated in response to demands and needs put forward by developing countries. The ICS activities focus on specific sectors within the areas of:

- Pure and applied chemistry
- Earth, environmental and marine sciences and technolgies
- High technology and new materials

Further information on ICS-UNIDO can be found at: http://www.ics.trieste.it

MAIN CERTIFICATION PROGRAMMES AND LABELS FOR EDP IDENTIFICATION

Biodegradable Products Institute / USA	http://www.bpiworld.org
Biodegradable Plastics Society / Japan	http://www.bpsweb.net
DIN CERTCO / Germany	http://www.dincertco.de

EDP and developing countries.

A number of developing countries are deeply interested in the development and promotion of the EDP concept as a way of reducing their environmental burdens as well as using their domestic oil and /or renewable resources for the development of a competitive industry.

Several countries are developing a sound concept of EDP, however, in several cases the focus in on "easy" solutions, namely blends of conventional non-degradable polymers (such as PE or PP) with degradable fillers (most commonly starch).

Such blends are being developed as biodegradable plastics although this is incorrect since the bio-stable olefinic component does not degrade and thus the whole plastics just disintegrate into fragments that remain and tend to accumulate in the environment.

The use of such materials can lead to turning visible pollution into less visible pollution.

ICS-UNIDO is involved in helping developing countries to avoid the promotion of misleading concepts on EDP by information spreading, awareness building, as well as by promoting the establishing of standardization, testing and certification systems through a series of international projects.

EDP

Step 2: *Mineralization*

In the second step the products of fragmentation are digested by microorganisms that use the energy stored in the fragmented molecules for their growth. This process is called *mineralization* and ultimately generates carbon dioxide, water and minor quantities of other biocompatible degradation products.

Mere fragmentation or dissolution may lead to visible disappearance of the material while leaving biostable macromolecular compounds behind as residues. In the environment these fragments or dissolved macromolecules can accumulate as 'organic sand' or move through the environmental water system with often unpredictable consequences. In a living organism they may accumulate and provoke a harmful response in the organism. Fragmentation or dissolution does not represent proof of environmental degradation.

The **environmental fate and toxicology** of degradation products are an integral part of any discussion of EDP. It is imperative that neither degradation nor the products obtained from it cause any durable alterations in the environment. Long-term sustainability can be assured only through an understanding of the complete degradation process with all its degradation stages and of the effects of degradation products.

Environmental factors causing degradation

Polymer degradation can be caused by a myriad of different environmental factors. The most commonly encountered are *heat*, *sunlight*, *oxygen, water, pollution, microorganisms (bacteria, fungi, algae, etc.), macroorganisms (insects, crickets, woodlice, snails, etc.), mechanical action, wind and rain* and so on. Depending on the active environmental factor, degradation can be classified into categories such as photo-degradation, thermal-degradation, bio-degradation, hydrolysis, oxidative degradation, etc. In real life it is common for two or more factors to be active simultaneously often leading to a synergy. *Composting* is an example of degradation in which more than one environmental factor comes into play. *In vivo* degradation, important for medical applications of EDP, is also considered a form of environmental degradation.

There are two main routes for EDP degradation, mineralization, and biomass formation. These routes are shown in the above figure. The left-hand route shows polymer degradation through biochemical means (enzymes). This requires the presence of proper microorganisms under suitable conditions (atmosphere, water, nutrients). If life-sustaining conditions are absent degradation cannot occur *via* this route.

The right-hand route differs in the sense that the initial breakdown of the macromolecule depends on an abiotic process, while the mineralization proceeds through biochemical pathways. Here, proper abiotic conditions and reagents (light, water, heat, etc.) are required to trigger fragmentation. If the trigger is not in place, degradation cannot occur.

Rate of degradation

Polymers in general are organic materials and despite the high stability of commercial plastics they all degrade with time. It is the rate of degradation that separates what we consider non-degradable polymers (polyethylene, nylon, etc.) from EDPs. Classification of a polymeric material as an EDP largely depends on its **rate of degradation** under certain conditions. The rates of degradation are set so as to avoid accumulation of polymeric materials in the environment. Established composting cycles are generally used as the yardstick for EDP degradation rates.

Standardization and Certification

The task of defining criteria by which a plastic can be classified as an EDP, such as the required degradation time and extent of degradation, was undertaken by several international groups of experts. Their work led to standards that define degradation and test methods to assess it. The common point, is that they all distinguish between initial *fragmentation* and *mineralization*, with CO_2 evolution as the ultimate measure of degradation.

MAIN STANDARDIZATION ORGANIZATIONS AND STANDARDS GOVERNING EDPs

ISO **International Organization for Standardization** http://www.iso.ch
ISO 14855: Determination of the ultimate aerobic biodegradability and disintegration of plastic materials under controlled composting conditions -- Method by analysis of evolved carbon dioxide
CEN **European Committee for Standardization** http://www.cenorm.be
CEN13432: Requirements for Packaging Recoverable Through Composting and Biodegradation
ASTM **American Society for Testing and Materials** http://www.astm.org
D6400-99: Standard Specification for Compostable Plastics
DIN **Deutsches Institut für Normung** http://www.din.de
DIN V54900: Prüfung der Kompostierbarkeit von Kunststoffen

Standards were the basis for the development of certification programmes through which EDP producers guarantee the public environmental degradability of their products. Current certification programmes have a national character, but due to their high level of compatibility cross certification programmes between different certification organizations are emerging. A certificate gives producers the right to use an approved and registered identification and labeling system.

Certification is the most efficient method of ensuring that consumers and the environment are not adversely affected by the introduction of materials under false claims that they are EDP. Developments in the last decade show that standarization of biodegradability and compostability of EDP paves the way for their large scale application.

This is of key importance in providing consumers with quality materials at acceptable prices.

- To achieve acceptance of EDP the industry as well as the general public must be willing to use them. This can best be supported by awareness building efforts regarding the benefits of these materials. Governments must pledge to work together with industry and non-governmental organizations to promote EDPs. Training and capacity building are an integral part of awareness building.

- EDP are strongly integrated into waste management strategies. To take full advantage of the properties of EDP they should become part of the organic waste stream and be treated after use. The emergence of composting facilities and separated waste collection are thus an important and necessary accompaniment to optimal EDP use. On the other hand EDP can spark interest in providing better solutions for organic waste, which normally represents a substantial part of the total waste stream. The best available method to evaluate the contribution of EDP in this complex scheme is through an integrated approach to resource and waste management employing life cycle assessment (LCA) methods as the measuring method.

- Finally, it is important that EDP receive proper technical and regulatory support. This can be done through legislation, as well as through the accompanying standards and certification schemes recognized by the appropriate national authorities. This kind of regulatory support can act to promote EDP use in cases where the overall benefit outweighs financial or organizational costs and helps to safeguard the public's trust in the safety of these materials.

EDP will be able to take their rightful place among other materials only if all these issues are addressed in their promotion. ICS-UNIDO activities reflect the complexity of this issue and attempt to combine awareness building and training with specific goals such as pilot plant or reference centre establishment and a strong regional emphasis.

Applications of EDPs

Many new EDP are currently in the developmental stage and important applications have begun to emerge in the areas of packaging, food, and the medical industry. At present, EDP have importance in two major fields of application:

1) packaging and other uses where they offer the convenience, safety and economy of conventional petro-plastics while minimizing waste management difficulties (high volume-low cost applications)
2) medical applications where they support new technologies such as controlled drug delivery, resorbable implants and tissue engineering (low volume - high cost applications)

Environmental / waste management applications

The use of EDP to alleviate solid waste management problems is a rapidly growing segment. The focus of EDP use is on including these wastes in composting treatment thus avoiding costly recovery and recycling schemes.

Target markets for EDP are:

Packaging materials - single or limited use disposable packaging and film applications.
Disposable non-woven and hygiene products (nappies, personal care, medical items).
Consumer goods - cups, plates, cutlery, containers, egg cartons, razors, toys etc.
Coatings for paper and film.
Marine plastics - fishing lines, nets, pots, etc.; plastics used in ships (Marpol treaty).
Agricultural mulch film and other agriculture related plastic products.
Loose-fill and rigid foam packaging products.

It is expected that specialty markets will emerge before large-scale use of biodegradable resins takes place. They will include toys, pens, planters or other products where biodegradability represents a novelty. At present the most widely practiced application of EDP are rubbish bags for organic waste, loose fill packaging, and agricultural mulch film. Despite the limited size of these markets EDP are experiencing a double digit annual growth. However, cost remains one of the major barriers to market penetration. Biodegradable resin costs are expected to decrease with higher production volumes.

Use of EDP in waste management is closely correlated with composting activities which offer the most common disposal treatment. Composting avoids costly collection and recycling schemes (e.g. for highly contaminated, low weight, high volume waste such as food packaging). Degradation can occur when the article is no longer needed (*e.g.* agricultural mulch films degrade in the field in one harvest season).

Bio-medical applications
The second area of EDP use is in medical and pharmaceutical applications. Their use started some thirty years ago with the development of surgical sutures based on aliphatic polyesters. These materials are built from monomers such as glycolic acid and lactic acid, which are normally present in the human body. The human body has a number of metabolic pathways that degrade such materials. Although degradation can proceed through oxidation, reduction, and enzymatic hydrolysis, the latter is the best understood and is commonly employed in the design of biodegradable polymers. The degradation products from the reaction should not provoke adverse reactions in the body.

Biodegradable materials are currently used for temporary applications such as implants. An implant is used by the body to support regeneration of normal functions. During the regeneration process the implant will degrade and be fully reabsorbed leaving no foreign residue in the body. A second operation for the removal of the implant, normal with metal implants, is not needed with EDP implants. Another important use of EDP in biomedical applications is in drug delivery where EDPs assist in providing the drug to the body at the right concentration, at the desired location and for the required period of time. Future developments are indicated by the continued extensive applied research of EDP use in drug delivery systems and tissue engineering. These areas represent significant growth areas for medical device manufacturers and pharmaceutical companies.

Biomedical applications represent an extremely important application of EDP although it consumes relatively small quantities. Nevertheless, this market is important since it takes full advantage of the functional properties of EDP. Biomedical applications of EDP provide opportunities for new product development, although the registration procedures for medical devices are a limit to the introduction of new materials.

EDP

Why Introduce EDP?

EDP materials and technologies will play a role in industries in the future. The wide range of possible applications allows for different approaches suitable world-wide. The main arguments for devoting attention to EDP are:

EDP represent a fast growing material basis for a more environmentally sustainable future.
These technologies are under development and offer great opportunities for growth.
EDP depend on locally available renewable resources that can be utilized locally thus creating opportunities for independent development in developing countries.
EDP span a very wide area of applications from low- to high-tech. Some do not require elaborate and expensive equipment.
Introduction of EDP is a tool to reinforce a more environmentally sustainable attitude in the general public.
EDP are universally applicable.

An Integrated Approach to EDP Promotion

EDP cannot achieve their full potential unless they are part of an integrated system aimed at promoting sustainable development, protecting the environment and encouraging the creation of functional innovative technologies. The role of public sector institutions should be to create an environment in which EDP use will be optimized, while industry and the general public will need to be convinced of the functional properties of EDP to accept them. Thus, an integrated approach to EDP promotion must be conducted.

- On the technical side it is imperative that suitable, efficient, and environmentally acceptable technologies exist for EDP production on an industrial scale. Suitable (renewable) resources for EDP production should be available locally and should not endanger food production or other critical resoures (e.g. water, energy, etc.) but rather alleviate existing environmental burdens. EDP are currently a niche market product, but these issues are being resolved and will allow EDP to enter mass market consumer applications.