BIO 3 MSc (Polymeric Biomaterials)

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Introduction

Polymeric biomaterials are chosen for different applications depending on their properties and are widely used in clinical applications such as dentistry, ophthalmology, orthopedics, cardiology, drug delivery, sutures, plastic and reconstructive surgery, extracorporeal devices, encapsulates and tissue engineering.

Polymer and environment

A world without plastics, or synthetic organic polymers, seems unimaginable today, yet their large-scale production and use only dates back to ~1950. Although the first synthetic plastics, such as Bakelite, appeared in the early 20th century, widespread use of plastics outside of the military did not occur until after World War II. The ensuing rapid growth in plastics production is extraordinary, surpassing most other man-made materials. Notable exceptions are materials that are used extensively in the construction sector, such as steel and cement.

The traditional polymer materials available today, especially the plastics, are the result of decades of evolution. Their production is extremely efficient in terms of utilization of raw materials and energy, as well as of waste release. The products present a series of excellent properties such as impermeability to water and microorganisms, high mechanical strength, low density (useful for transporting goods), and low cost due to manufacturing scale and process optimization .

Before we use materials that can accumulate in nature, we must think about reducing their consumption, reusing and recycling (either by reuse of raw materials, or by use of the energy of combustion) [3]. However, certain parts that are formed by small amounts of polymer (ie, a few grams) and may still be contaminated by food are difficult to be collected from nature, cleaned, sorted and recycled, both from the economic and also from the environmental (energy consumption and soil pollution of the process) point of view. This is the case of plastic bags and packaging, especially plastics used in food, in medical and hygiene. In these cases, the use of biodegradable polymer materials may be an excellent solution to the environment .

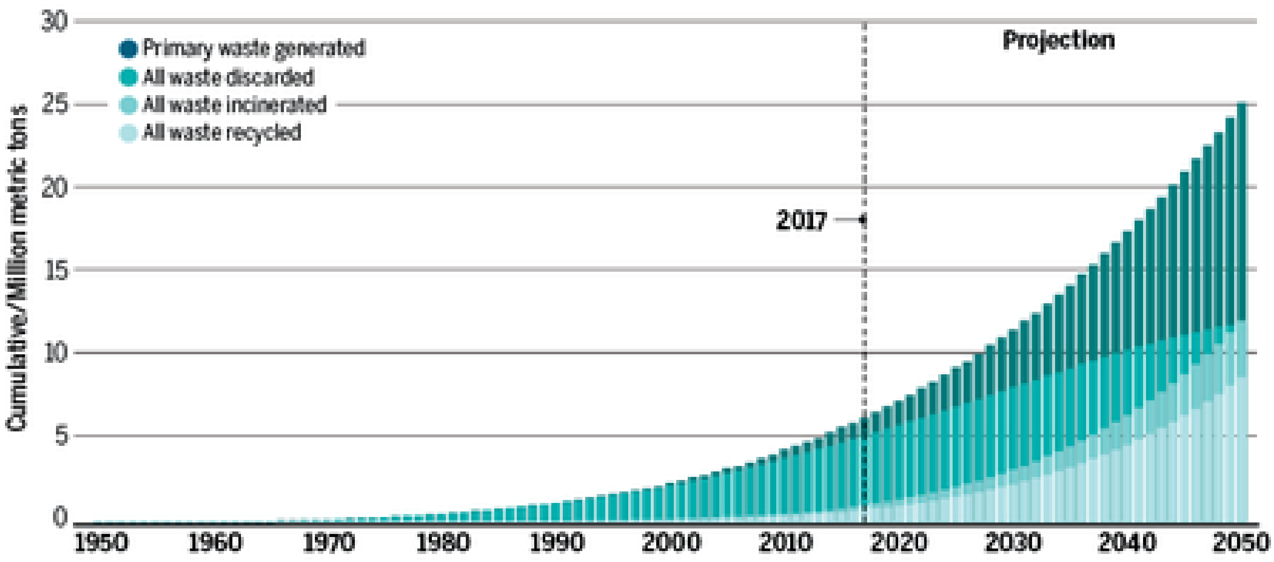
During the 1960s percipient environmentalists became aware that the increase in volume of synthetic polymers, particularly in the form of one-trip packaging, presented a potential threat to the environment, what became evident in the appearance of plastics packaging litter in the streets, in the countryside and in the seas .

PLASTIC pollution in oceans is a growing problem. Over time, movement of waves and exposure to the sun breaks the material into tiny particles called microplastics which harm even the smallest oceanic organisms. Two studies published in the journal Current Biology on examined the effects of microplastics on lugworms, which are a source of food for fish and birds and play an important role in nutrient recycling.

One of the studies found that lugworms are up to 50 per cent less energetic if ocean sediments contain significant amounts of microplastics. This had a serious effect on their growth and reproduction.

By 2050, we'll have produced 26 billion tons of plastic waste

Historical data and projections to 2050 of plastic waste production and disposal. "Primary waste" is plastic becoming waste for the first time and doesn't include waste from plastic that has been recycled.



Classification Based on Molecular Forces:

The mechanical properties of polymers are governed by intermolecular forces, e.g., van der Waals forces and hydrogen bonds, present in the polymer, these forces also bind the polymer chains Under this category, the polymers are classified into the following groups on the basis of magnitude magnitude of intermolecular inter molecular forces present present in them, they are :

(i) Elastomers (ii) Fibers (iii) Liquid resins (iv) Plastics [(a) Thermoplastic and (b) thermosetting plastic.

Elastomers: These are rubber – like solids with elastic properties. In these elastomeric polymers, the polymer chains are random coiled structure, they are held together by the weakest intermolecular forces , so they are highly amorphous polymers. A few 'crosslinks' are introduced in between the chains, which help the polymer to retract to its original position after the force is released as in vulcanised rubber such as neoprene .

Fibers: If drawn into long filament like material whose length is at least 100 times its diameter, polymers are said to have been converted into 'fibre'

Fibres are the thread forming solids which possess high tensile strength and high modulus , Examples are polyamides (nylon 6), polyesters .. etc.

Liquid Resins: Polymers used as adhesives, potting compound sealants, etc. in a liquid form are described liquid resins, examples are epoxy adhesives

Plastics: A polymer is shaped into hard and tough

Typical examples are polystyrene, PVC and polymethyl methacrylate. They are two types

(a)Thermoplastic and (b)Thermosetting plastic.

Advantages of biopolymers

- Not expensive.
- Easy to fabricate.
- Resistance to corrosion.
- Wide range of physical, chemical and mechanical properties.
- Low density (low weight).
- May be biodegradable.
- Good biocompatibility.
- Low coefficients of friction.

Disadvantages of Polymers

- Low mechanical strength.
- Thermo sensitive.
- Easily degradable.

- Absorb water & proteins etc.
- Wear & breakdown.
- Sensitive to sterilization techniques because of their permeability and porous structures.
- Bacterial colonization because of their organic structure.

In orthopedic applications (screws…)

- Metal alloys present greatest load bearing.
- Polymers present lower load bearing.

In vascular applications (stents…)

- Magnesium alloys degrade too fast in biological environment and they dissolve in the body.
- Polymers degrade slower than magnesium alloys.

Biodegradable Polymers

Biodegradable polymers are designed as temporary structures having the desired geometry and the physical, chemical, and mechanical properties required for implantation.

Biodegradable polymeric biomaterials have been experimented with as (1) vascular grafts (2) vascular stents, (3) nerve growth conduits, (4) defected bone, (5) ligament/tendon prostheses.

Mechanisms causing degradation

Physical

- sorption/swelling,
- softening,
- dissolution,
- stress cracking,
- fatigue cracking.

Chemical

- hydrolysis,
- oxidation
- enzymatic

Polymers used as biomaterials

Although hundreds of polymers are easily synthesized and could be used as biomaterials only ten to twenty polymers are mainly used in fabrication of medical device from disposable to long-term implants.

1-Polyvinylchloride (PVC)

The PVC is an amorphous. PVC sheets are used in blood and solution storage bags. PVC tubing is commonly used in intravenous (IV), dialysis devices, catheters, and cannulae (i.e. mostly for external use).

2- Polyethylene (PE)

HDPE is used in pharmaceutical bottles.

LDPE is used for flexible container applications, disposable for packaging.

LLDPE(linear low density) is employed in bags due to its excellent puncture resistance.

UHMWPE(**Ultra-high-molecular-weight polyethylene)**Also known as **high-modulus polyethylene**, (**HMPE**), or **high-performance polyethylene** (**HPPE**), has been used for fabrication of orthopedic implant, especially for load bearing applications such as an acetabular cup of total hip and the surfaces of patellar of knee joints.

3- Polypropylene (PP)

This is a very simple polymer whose structure is almost similar to PE. It's mechanical properties are also balanced. The one thing that sets this one apart is the hing property that it has.PP is used to make disposable syringes, packaging for devices, solutions, and drugs, suture, artificial vascular grafts, etc.

4- Polymethylmetacrylate (PMMA)

PMMA is used broadly in medical applications such as a blood pump and reservoir, membranes for blood dialyzer, and in vitro diagnostics. It is also found in contact lenses and implantable ocular lenses due to excellent optical properties, dentures, and maxillofacial prostheses due to good physical and coloring properties, and bone cement for joint prostheses fixation.

Bone cement: Mixture of polymethylmethacrylate powder and methylmethacrylate monomer liquid to be used as a grouting material for the fixation of orthopedic Joint implants.

5- Polystyrene (PS)

PS is commonly used in roller bottles.

6- Polyesters

It's used for artificial vascular graft, sutures as a soft matrix or coating.

7- Polyurethanes

They are widely used to coat implants and arteries, cardiovascular prostheses, catheters and pacemakers (as insulator).

8- polycarbonates

Polycarbonates have found their applications in the heart/lung assist devices, food packaging**.**

9- Polyethylene terephthalate, called Dacron,

Is used in the artificial heart valves. Dacron is used because tissue will grow through a polymer mesh. Dacron is used for large arteries.

In general the biopolymer may be:

Thermoplastic biopolymer: materials that can be shaped more than once. (Used as replacements for blood vessels.).

Thermosetting biopolymer: materials that can only be shaped once (Used in dental devices, and orthopedics such as hip replacements.).

Elastomer biopolymer: material that is elastic. If moderately deformed, the elastomer will return to its original shape. Used as catheters.

Polymers In Specific Applications

Application	**Properties and design requirements**	**Polymers used**

Dental	• stability and corrosion resistance. • strength and fatigue resistance. • good adhesion/integration with tissue. • low allergenicity.	PMMA polyamides
Ophthalmic	• gel or film forming ability • oxygen permeability	polyacrylamide PHEMA (polyhydroxyethylmethacrylate)
Orthopedic	• strength and fatigue resistance. • good integration with bones and muscles	PE, PMMA
Cardiovascular	• fatigue resistance, lubricity, • sterilizability	silicones, Teflon, poly(urethanes)
Drug delivery	• compatibility with drug, biodegradability	silicones, HEMA
Sutures	• good tensile strength, strength retention • flexibility, knot retention.	PP, nylon

Biological Polymers

Biopolymers are natural materials such as carbohydrates, proteins, cellulose, DNA and RNA that produced by living organisms.

Carbohydrates.

Proteins are big molecules present in living cells (animal tissues, skin, nails, muscles).

Proteins are polyamides

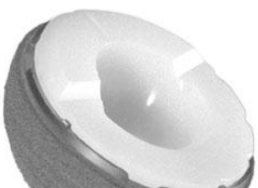
Cellulose

DNA- Deoxyribonucleic Acids.

RNA - Ribonucleic Acids.

DNA & RNA are polyesters (of H_3PO_4).

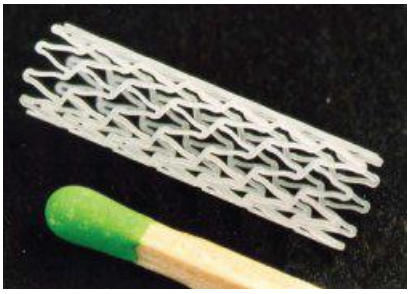
Some examples of polymeric biomaterials:



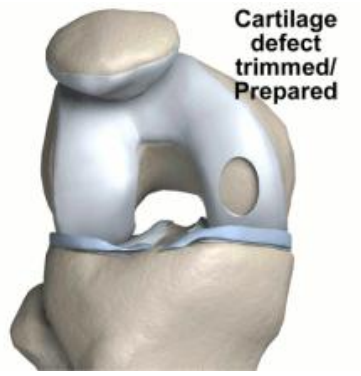
acetabular cup of hip joint

Spinal cage for spine fusion

Vascular Implants & Stents



Cartilage



Artificial heart valve