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# A COMPREHENSIVE REVIEW: IMPORTANCE OF POLYMERS IN CONTROLLED DRUG DELIVERY SYSTEM

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ABSTRACT

Drug delivery makes considerable use of polymers because of their bulk and surface properties. Polymers are used in both drug delivery systems and drug formulations. For regulation of drug distribution, implants are used as drug delivery devices. Because of their optimal drug loading and releasing properties, polymers used in colloidal drug carrier systems—which are made up of tiny particle that show tremendous advantage in drug delivery systems. Systems of polymeric nanoparticulate matter are widely accessible and possess a well-established chemistry. There are polymers that are non-toxic, biodegradable, and biocompatible. The function of polymers in the pharmaceutical drug distribution of therapeutic agents is the main topic of this review. The polymers are employed as drug delivery vehicles at the intended target, because biodegradable polymers may release pharmaceuticals at a consistent rate of degradation, they are frequently employed to deliver medications to specified body sites. Predefined rates of drug distribution are also achieved through the use of natural polymers. The medication is released from these polymers through the processes of degradation, diffusion, and swelling. They are employed in the pharmaceutical business as binders, film coatings to cover up bad tastes, stabilizers, and ways to change the release properties of drugs for controlled drug delivery.

**Key words:** Polymer, Polymer Drug Delivery, Biocompatible polymer, smart polymer, Implants

## INTRODUCTION

**THE POLYMERS:** Polymers and macromolecules have both found use in the technology of extended release medication formulations. Their primary goal is to guarantee that the patient's body has a steady concentration of the therapeutic substance for the designated period of time (e.g., 8–24 hours). As a result, the class of medications can stop giving the medication more than once during the day and lower its overall dosage. Prolonged medication forms are typically used to treat mental health issues, coronary artery disease, diabetes, and ailments of the heart and digestive tract. The process of coating, incorporating, complexing, or bonding on the ionites can decrease the absorption of the medicinal substance when employing sustained release drug forms

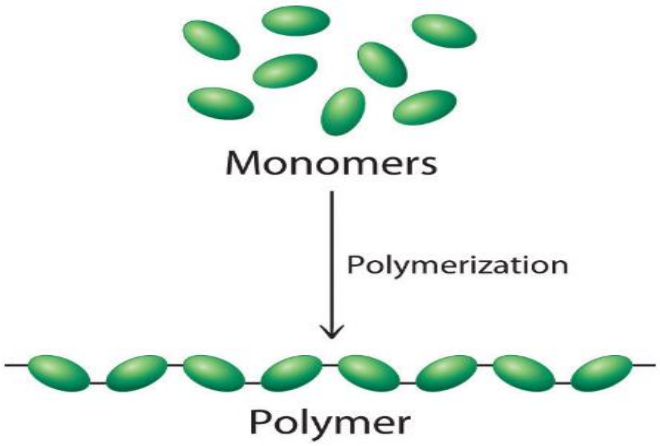


Fig: 1 Polymer formation by polymerization

Large chained macromolecules with a range of functional groups that can be combined with other materials of both low and high molecular weight and customized for any purpose are known as polymers. The foundation of pharmaceutical drug delivery systems is polymers. Because they provide special qualities that no other material can match, they have been shown to have numerous applications in drug delivery. Polymers are a valuable tool for controlling the rate at which drugs release from formulations. They are also enhanced when employed as taste-masking, stabilizing, and protecting agents in oral drug administration[1]. Polymers offer better pharmacokinetic quality; they are becoming a crucial component of drug delivery systems. They target tissue more specifically because they have a longer half-life than traditional tiny medication molecules. The fields of polymer therapies and nano-medicines have made extensive use of polymers[2]. The use of polymers in reservoir-based drug delivery systems has advanced significantly thanks to the development of hydrogels and liposomes.The usage of polymeric materials in medicine is expanding quickly. Numerous biomedical domains, including drug delivery systems, tissue engineering scaffold development, implanting artificial organs and medical devices, prosthetics, dentistry, ophthalmology, bone regeneration, and many more, have found use for polymers.[3] One of the primary instruments utilized to regulate the medication release rate from the formulations has been polymers.Because polymers have special qualities that no other material can match, they have found extensive applications in the administration of drugs.

Numerous innovative medication delivery systems have been developed as a result of developments in polymer science. Designing polymers for diverse drug delivery applications can be facilitated by giving due consideration to both surface and bulk properties.[4] These more recent technological advancements include the chemical alteration of drugs, drug trapping in polymeric matrices or pumps positioned in specific areas, and carrier-based drug delivery. The effectiveness of medication therapy is increased by these technological advancements in drug delivery and targeted strategies, which enhance human health[5]. Chemical engineers, polymer chemists, and pharmaceutical scientists work to develop bioactive compounds with predictable, controlled distribution.[6] Large-scale Because of their well-established biocompatibility and biodegradability, biodegradable polymers have found extensive application in the biomedical field. Polymers are typically employed as implants in the biomedical field, where they are meant to last for a long time. These advancements help reduce side effects and other patient annoyances while also increasing the effectiveness of medical care.[7]

## ADVANTAGES OF POLYMERS

Three benefits can be obtained from polymeric drug delivery products:

**Localized drug delivery:**

By implanting the device exactly where the medication is needed, systemic exposure to the medication can be minimized. particularly for toxic medications that have a number of systemic adverse effects.

**Drug delivery that lasts:**

The medication is given gradually over time, obviating the need for repeated injections.

This function can help increase patient compliance, particularly with medications that need to be injected frequently and have chronic indications.

**Drug stabilization:**

By shielding the medication from the physiological milieu, the polymer can increase the drug's stability in vivo. This characteristic makes the method appealing for the administration of medications that are labile, such as proteins[8].

## TYPES OF POLYMER FOR DRUG DELIVERY SYSTEM[9]

### *Polymers as for floating drug delivery system*

To target the delivery of a drug to a specific region of the gastrointestinal tract, such as the stomach, floating drug delivery systems typically use polymers. Various natural polymers have been investigated for their potential in stomach-specific drug delivery, including chitosan, pectin, xanthan gum, guar gum, gellan gum, karaya gum, psyllium husk, starch, and alginates.[10]

### *Mucoadhesive medication delivery systems require polymers.*

With benefits like increased polymer residence time, improved penetration, site-specific adhesion, and enzymatic inhibition, the next generation of mucoadhesive polymers for buccal drug delivery will surely be used for the buccal delivery of a wide range of therapeutic compounds. The delivery of medicinal macromolecules has great potential when it comes to this family of polymers. The most promising field of current research efforts targeted at the safe and efficient delivery of medications via the buccal mucosa seems to be the application of lectin and "lectinomimetics.[11]

### *Polymers for medication delivery implants*

Because of their improved biocompatibility and ability to conform to tissue without breaking during insertion or tissue reconfiguration processes, polymer microneedles are of interest for implanted drug delivery. Several polymers, including as polydimethylsiloxane (PDMS), polylactic and polyglycolic acid (PLGA), block copolymer hydrogels, SU-8 photoresist, and polyimide, have been used to manufacture these devices. In 2010,

Bernardo and colleagues created a gadget that combines the benefits of active fluidic delivery systems with the biocompatibility and flexibility of polymer microneedles in a straightforward microfluidic design. While the electrochemical release and dose control mechanism of this device is identical to that of our earlier work (Chung and Erickson), it is now integrated into a flexible system instead of its silicon predecessor.[12]

***Polymers for Long-Term Effect***

Utilizing a novel, very effective osteogenic chemical, biodegradable microspheres are created using the polymer utilized in the sustain release method. To attain the continuous release of 3-ethyl-4-(4-methylisoxazol-5-yl)-5-(methylthio) thiophene-2-carboxamide, a novel and powerful osteogenic agent for the management of bone disorders, microspheres containing BFB0261 were created, along with newly synthesized biodegradable polymers or copolymers, namely three poly (d, l-lactic acid) (PLA), four poly (d, l-lactic acid–co-glycolic acid) (PLGA), and eight poly (d, l-lactic acid)-block-poly(ethylene glycol) (PLAPEG) and microspheres containing BFB0261. The microspheres' release pattern was assessed.[13]

***Polymers for Colon Targeted Drug Administration:***

A significant part of the colon-targeted drug delivery system is polymer. It shields the medication against deterioration or leakage into the small intestine and stomach. Moreover, it guarantees the medication's quick or regulated release in the proximal colon. Using dicarboxylic acid linkers (succinate and glutarate), McLeod et al. produced glucocorticoid-dextran conjugates by attaching dexamethasone and methylprednisolone to dextran. When there is a high bacterial count in the cecal and colonic contents, dextran conjugates quickly breakdown but resisted hydrolysis in the contents of the upper GI tract.[14]

***Polymers in tissue engineering***

A wide range of natural–origin polymers with special focus on proteins and polysaccharides might be potentially useful as carriers systems for active biomoleculesor as cell carriers with application in the tissue engineering field targeting several biological tissues.
Several polyshaccrides -based polymers in the tissue engineering such as chitosan, starch, alginate etc.[15]

***Micelles made of polymers***

The development of polymeric micelles (PMs) was prompted by the urgent demand for highly selective drug carriers. Hydrophobic, poorly water soluble anticancer medicines can be encapsulated in PMs made of an amphiphilic block copolymer. Significantly, key characteristics of PMs as drug carriers, such as stability, loading capacity, and drug release kinetics, enable PMs to be selectively delivered to the tumor site through a passive process known as the increased permeability and retention effect.[16]

***Polymers utilized in targeted medication delivery micro and nanoparticles***

These polymers are biocompatible and biodegradable, and much research has been done on them lately. The pharmacokinetics of polymeric nano carriers, including poly (DL-lactide-co-glycolide), have demonstrated potential for both cellular and whole-body administration (passive targeting). The process of chemically attaching a drug to a targeting component that interacts strongly with antigens or receptors present on the target tissue is typically used to accomplish active drug targeting. This results in the drug being preferentially accumulated in the targeted organ, tissue, or cells.[17]

***Polymer drug conjugate***

These macromolecular prodrugs consist of at least three components: a natural or synthetic, water-soluble polymeric carrier (typically of 10,000–100,000 Da), a biodegradable polymer–drug linkage (often an ester or peptidyl linkage), and a bioactive antitumor agent. Polymer–drug conjugates achieve tumour-specific targeting through the enhanced permeability and retention (EPR) effect. N-(2-hydroxypropyl)methacrylamide (HPMA) copolymer-doxorubicin (PK1; FCE28068) phase I/II clinical trials demonstrated a four- to five-fold reduction in anthracycline-related toxicity, and no cardiotoxicity was seen despite cumulative doses up to 1680 mg/m2 (doxorubicin equivalent).[18]

## CLASSIFICATION OF POLYMERS

**Polymer Classification**

Based on several factors, the polymers are divided into different types.

1. **Polymers based on origin or source**
   - **A. Natural polymers:** Natural polymers are defined as *materials that widely occur in nature or are extracted from plants or animals*. Ex: Chitosan, pectin, alginate, gelatin, albumin, collagen,cyclo dextrin.

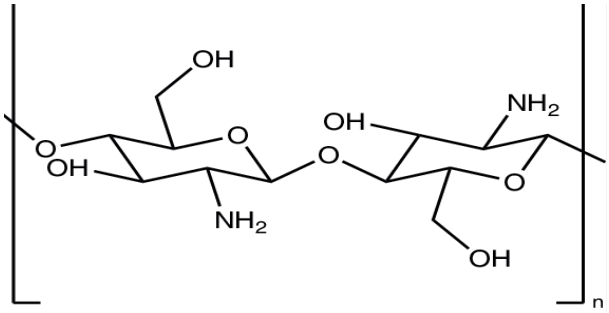


Fig:2 Structure of Chitosan

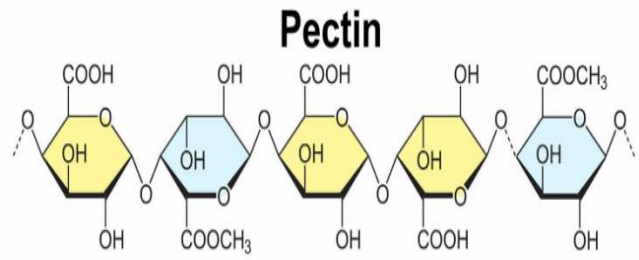


Fig: 3 Structure of Pectin

**B. Semi synthetic Polymers**

Semi-synthetic polymers are those *that are derived from nature itself but are made to undergo chemical processes to enhance their* quality. Ex.Hydroxy Propyl Methyl Cellulose (HPMC), Methyl Cellulose (MC), Hydroxy Propyl Cellulose (HPC).

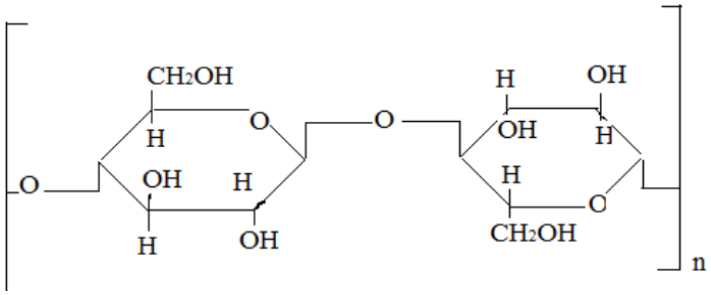


Fig: 4 Structure of HPMC

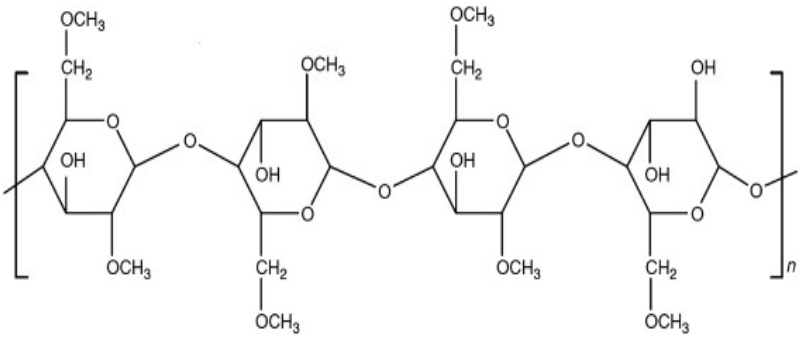


Fig: 5 Structure of Methyl Cellulose

### C. Synthetic Polymers

Synthetic polymers are defined as *polymers that are artificially produced in laboratories*. These are also known as man-made polymers. Ex.Polyethylene, polylactic acid, polypropylene, polyglycolic acid, polyhydroxybuterate, polyanhydride, and polyacrylamide are examples of synthetic polymers.

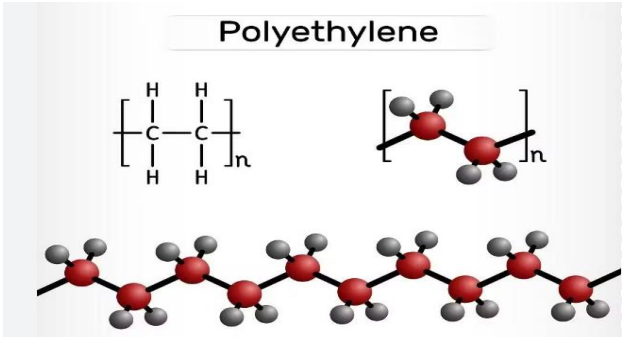


Fig:-6 Structure of polyethylene

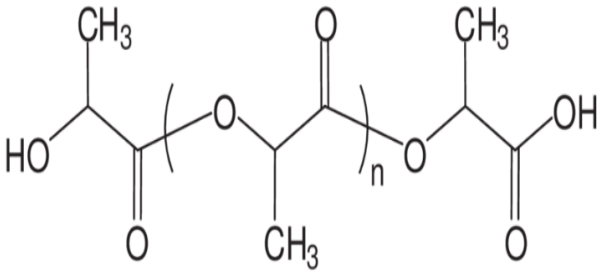


Fig:-7 Structure of Polylectic Acid

**2. Based on degradation polymers are classified in to different types**

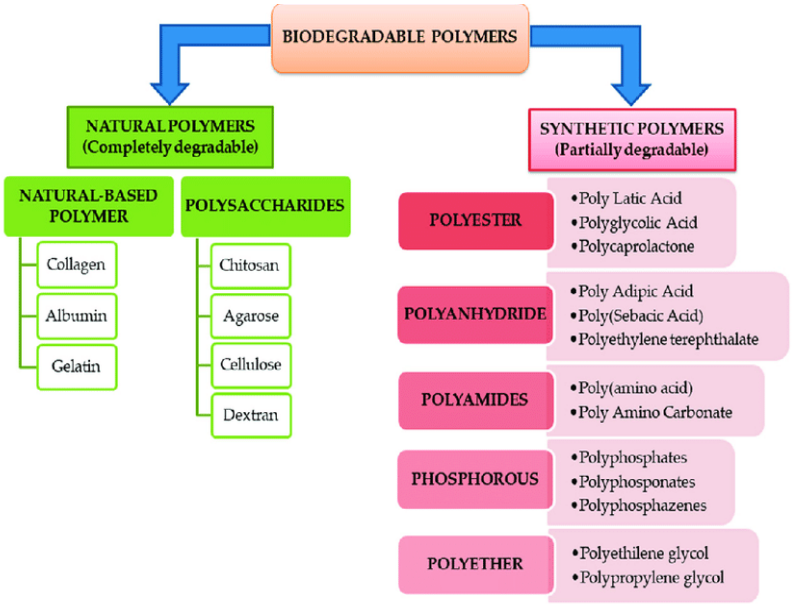


Fig:-8 Classification of Degradation of polymer

## IMPACT OF POLYMERS ON DRUG RELEASE

***Diffusion***

when an active ingredient, such as a medication, diffuses through the polymer that makes up the controlled-release device, it happens. The drug diffuses when it leaves the polymer matrix and enters the surrounding environment. When the delivery system is introduced into the biological environment, the combinations of polymer matrices and bioactive agents selected must enable the drug to diffuse through the pores or macromolecular structure of the polymer without causing any changes to the polymer itself.[19]

***Reduction***

Once the active ingredient has been released, biodegradable polymers break down naturally in the body through biological processes, negating the need to remove a drug delivery system. The majority of biodegradable polymers are made to hydrolyze into increasingly smaller, physiologically acceptable molecules as the polymer chains break down. Certain degradable polymers, such as polyanhydrides and polyorthoesters, only degrade at their surface, causing a release rate that is proportionate to the drug delivery system's surface area.[20]

***Swelling***

When inserted within the body, they will absorb water or other bodily fluids and swell, even if they are initially dry. The medicine is able to permeate through the swollen network and into the surrounding environment because the swelling increases the formulation's aqueous solvent content and polymer mesh size.[21]

## POLYMER USAGES IN DRUG DELIVERY

**Polymers usages in conventional dosages form**

1. In Tablets:-As binders for enteric-coated tablets to cover up an unpleasant flavor.
2. Liquids: Viscosity enhancers to regulate the movement
3. Semisolids: When making gels
4. In creams.
5. In Topical Adhesions as transdermal patch[22]

**Utilization in the field of biomedicine**

**A. Applications of Synthetic Water-Soluble Polymers**

i. Poly (acrylic acid) it is used as pharmaceutical medicines, cosmetics, cationic drug immobilization, and carbopol polymer base.
ii. Poly (ethylene oxide) as a swelling agent, flocculent, coagulant, and very high molecular weight up to a few million.
iii. Poly (ethylene glycol); as plasticizer, wax and suppository base
iv. Poly (vinyl pyrrolidone) is used to prepare betadine, an iodine complex of PVP that is less toxic than iodine and can be used in tablet granulation or as a plasma substitute.
v. Water-soluble packaging, tablet binder, and tablet coating made of poly (vinyl alcohol) Proteins can be separated using polyacrylamide gel electrophoresis according to their molecular weights, coagulants, and absorbents.

**B. Polymers Based on Cellulose**

i. Cellulose ethyl Sustained release applications using an aqueous coating technique that is both dispersible and insoluble in water.
ii. Polymethyl methacrylate Superdisintegrant and stabilizer for emulsion.
iii. Celluloses that are hydroxyethyl and hydroxypropyl.
iv. Water and alcohol soluble, tablet coating.
v. Methyl hydroxypropyl cellulose Tablet matrix and coating binder, gelatin substitute as capsule filler 6. Enteric coating made of cellulose acetate phthalate.

**C. Hydrocolloids**

i. Alginic acid medicinal products for use orally and topically; thickening and suspending agents in a range of pastes, creams, and gels; stabilizing agents for emulsions of oil in water; binder and disintegrant.
ii. Carrageenan: - Viscosifier and modified release.
iii. Chitosan: mucoadhesive dosage forms, fast release dosage forms, controlled drug administration applications, and cosmetics.
iv. Acid hyaluronique decrease in scar tissue and cosmetics.
v. Acid pectinic medication administration

**D. Water-Insoluble Biodegradable Polymers**

Glycolide-lactide polymers microparticle–nanoparticle for protein delivery.

**E. Starch-Based Polymers**

Among the ingredients in tablets and capsules are starch glideant, diluent, disintegrant, and tablet binder. Glycolate of sodium starch Superdisintegrant for oral administration of tablets and capsules

**F. Smart polymers**

Polymers that adapt to changes in their surroundings are known as smart polymers. nsive polymers in medicine exhibit property changes in response to alterations in biological circumstances.[23] Temperature, pressure, pH, electric field, magnetic field, light, shift in concentration, ionic strength, redox potential, and other factors are examples of the different stimuli.[24] Such stimuli can cause reactions such as disintegration, swelling, precipitation, conformational changes, and modifications to the hydrophobic and hydrophilic qualities of an object. When designing oral drug delivery devices, the GI tract's pH changes are taken into account.[25]The pH of the enlarged and malignant tissue varies dramatically. When complex polymer structures undergo deprotonation or protonation in an acidic environment, polymer-bound medications are liberated in these tissues. Oral protein administration has been tried with P (MAA-g-EG), a poly (methacrylic acid) jointure with PE.[26] Changes in the characteristics of polymers can be applied to:

- Stick to the surface of the cell.
- Disintegrate the cell membrane and
- Release a chemical that is physiologically active.
- Micelles, polyplexes, and polymer drug conjugates are the three main categories into which stimuli-responsive polymers can be divided.

**G. Innovative Drug Delivery Systems with Polymers**

Polymers are being used by pharmacologists, scientists, and chemical engineers to create sustained release formulations and controlled drug release systems. Micelles, dendrimers, liposomes, polymeric nanoparticles, cell ghosts, microcapsules, and lipoproteins are examples of novel drug delivery systems. By avoiding under- or overdose, recent developments in polymer-based encapsulations and controlled drug release systems aid in the regulation of medication administration.[27]

## Advantages and limitations of polymers in case of novel drug delivery system

**Advantages**

1. Polymers used in colloidal drug carrier systems, consisting of small particles, show great advantage in drug delivery systems because of optimized drug loading and releasing property.[24]
2. A polymer (natural or synthetic) is aggregated with a drug in controlled drug delivery and hence it gives an effective and controlled dose of dug avoiding overdose.[24]
3. The degradable polymers are ruptured into biologically suitable molecules that are assimilated and discarded from the body through normal route.
4. Reservoir-based polymers have several benefits, including lowering antagonistic side effects and increasing the solubility of incompetently soluble medicines.[27]
5. While Quantum Dots are solely optically detectable, magneto-optical polymer coated and targeted nanoparticles are multimodal (optical and MRI detection).
6. Certain Quantum dots include Cd, which is known to be harmful to people. Because iron oxides and polymers are known to be safe, magneto/optical nanoparticles, whether polymer coated or targeted, have a bright future.
7. Since 1960, dextrans, a common polymer, has been utilized to coat iron oxide (plasma expander and affinity for iron) and has been used to treat iron anemias.
8. Certain polymers, such as polysiloxanes for insulation and polyurethanes for flexibility, are used for their intended non-biological physical qualities when released under regulated conditions.
9. Modern polymers, such as poly 2-hydroxy ethyl methacrylate, polyvinyl alcohol, and polyethylene glycol, are employed due to their leachable impurity-free nature and inert qualities.[27]
10. In the case of biodegradable polymers, the system is biocompatible, it won't ever exhibit dosage left behind, and the polymer will retain its characteristics till the medication has run out.

**Disadvantages, Difficulties and challenges**

1. Because microspheres are fundamentally batch processes, it is difficult to scale up the process and expensive to produce in large quantities.[28]
2. The size distribution of the microsphere particles can be replicated, however the outcome is typically non-uniform and the standard deviation is half of the average size. This happens frequently. Since the size of the sphere directly affects both syringability and the rate at which the drug will be delivered, the size distribution should be as narrow as possible.
3. The presence of aqueous-organic interfaces and organic solvents on encapsulated pharmaceuticals can have negative effects, such

as removing the microspheres' bioactivity.

4. The task is not simple. Since most organic solvents are poisonous, it is difficult to completely eliminate them, and the amount of leftover solvents in the microsphere should be regulated.
5. The challenge of accurately constructing systems with precisely regulated release rates is a major impediment to the development of biodegradable polymer microspheres for controlled-release medication delivery applications.
6. Compared to solid microspheres, core-shell microparticles are much harder to produce.
7. Because the microspehre's shell and core must be immiscible, handling and constructing its design is difficult.
8. Hydrogels can enlarge quickly when exposed to water, which could cause the medicine to release from the gel more quickly than intended and cause the polymer to break down.[29] When hydrophilic pharmaceuticals are administered via hydrogel systems, there is a release period that ranges from hours to days; this release period is thought to be significantly shorter than that of hydrophobic polymer-based delivery systems, such as microspheres or nanospheres.
9. Electrical stimulation of conducting polymers holds the potential for regulated medication delivery. Polyprrole (Ppy) is one instance of such a polymer.[29] However, because of their restrictions with regard to the drug's molecular weight and dopant selection, they are not widely used.
10. Hepatic first-pass metabolism[30] and gastrointestinal tract enzyme degradation are obstacles to the oral delivery of some pharmacological groups, primarily peptides and proteins.

## DRUG DELIVERY SYSTEMS: POLYMER REQUIREMENTS FOR DRUG DELIVERY DEVICES

**Dendrimers**

Dendrimers are hyperbranched, monodisperse (uniform size particles in a dispersed phase), 3-D molecules of size 1 - 100 nm macromolecules. They accommodate both hydrophilic and hydrophobic medicines, which helps them solubilize. They are made up of three structural parts,

1. Core central(multi-functional )
2. Divisional units
3. Surface teams

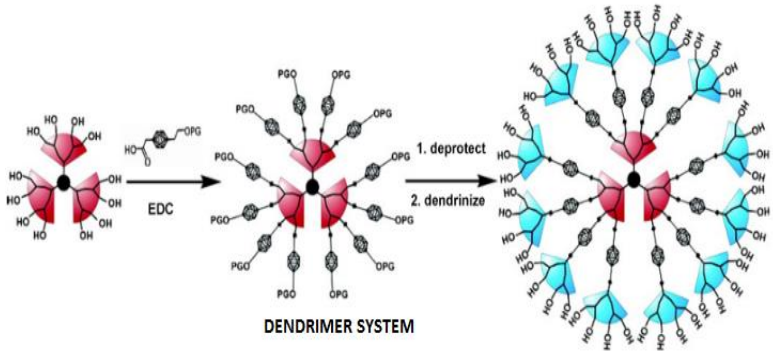


Fig: 9 Dendrimer System as Drug Delivery Devices

**Polymeric-Nano Particulate Systems**

Depending on how they were prepared, these could be nanospheres or nanocapsules.

**Microspheres and microcapsules**

Micro/Nano spheres are a type of matrix system where the medication is distributed throughout the particle's body within the polymer. Micro/Nano capsules are vesicular structures with a drug-containing cavity and an aqueous or oily core.Drugs are delivered by polymer degradation or diffusion through the micro/nanosphere and micro/nanocapsule. It is possible to inject or swallow micro/nanospheres and micro/nanocapsules. To treat prostate cancer, Lupron Depot is an injectable microsphere that entraps LHRH and is composed of leuprolide acetate and lactic acid-glycolic acid copolymer.

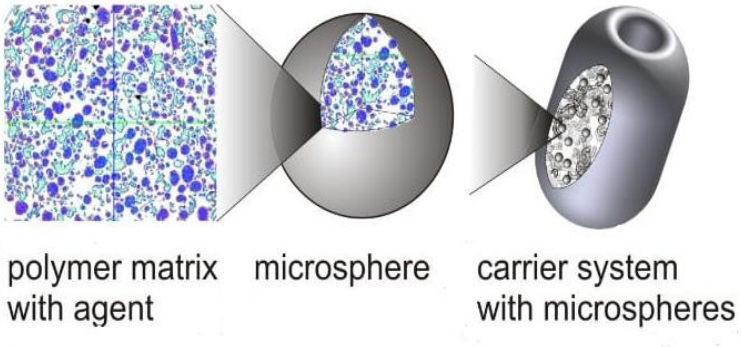


Fig: 10 Microsphere system

***Hydrogel System***

Three-dimensional, cross-linked networks of water-soluble polymers make up hydrogels. Polymers that are synthetic or natural can be used to create hydrogels. They have a high absorption capacity. Because they are biocompatible and inert to many medications, biodegradable hydrogels are being employed as carriers for controlled drug delivery. Because hydrogels have a relatively high porosity, the drug's diffusion coefficient plays a critical role in determining how quickly the drug releases. Controlling the degree of cross-linking allows hydrogel porosity to be tailored, which in turn affects how quickly the drug particles that are entrapped are delivered.

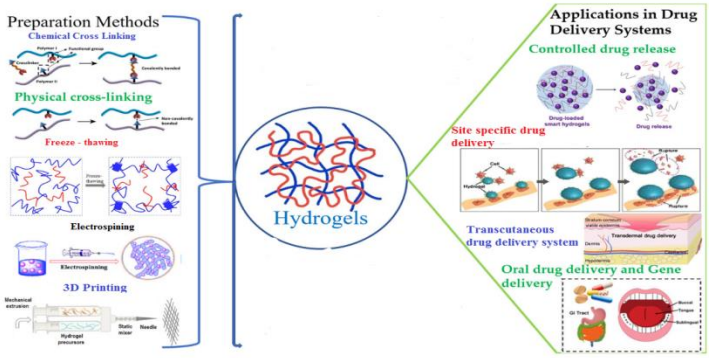


Fig:- 11 Hydrogel system for polymer administration

**Solid – Lipid Nanoparticles**

Solid lipid nanoparticles are a type of carrier system where melted lipid is homogenized under high pressure or microemulsified in an aqueous surfactant. They have a solid hydrophobic core and are stable colloidal systems. The dissolved or distributed medications are found in the core. Applying hydrophilic polymers, such as polyethylene glycol (PEG), to the surface reduces their hepatic absorption and increases their bioavailability. It traps both lipophilic and hydrophilic medications. For oral formulations, ibuprofen-containing solid lipid nanoparticles mixed with dextran hydrogels are appropriate.

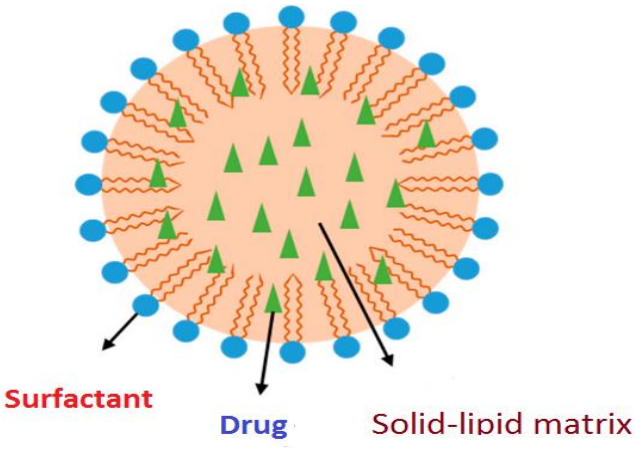


Fig: 12 Solid Lipid Nanoparticles system

***Magnetic Nanoparticles***

Drugs are injected into the bloodstream bound to magnetic nanoparticles, such as dextran-coated magnetite or oxidized iron. Outside the body, a strong magnetic field is created, which extracts these medications from suspension and transports them to a specific illness site. By applying a PEG or dextran coating, these become stable water dispersible systems. [31]

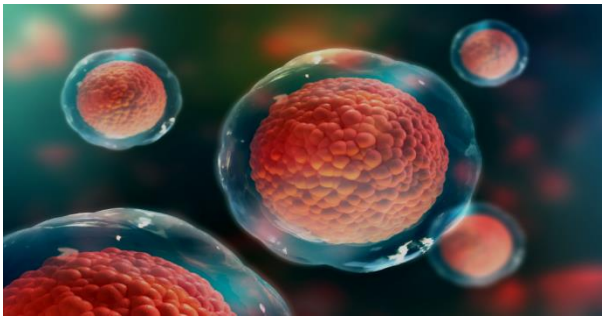

Fig: 13 Magnetic nanoparticles polymeric system

**Polymeric Micelles**

Individual amphiphilic di/tri block co-polymers spontaneously self-assemble to form the core shell structure of polymeric micelles.Their hydrophilic and hydrophobic areas are advantageous for poorly soluble medicines. Hydrophobic block polymer blocks, such as poly-(propene glycol), poly-(caprolactone), etc., comprise the core, while hydroplilic polymer (PEG) makes up the shell.

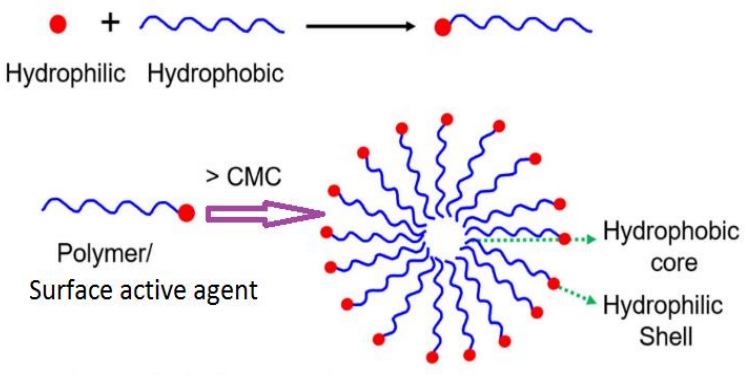


Fig: 14 Polymeric micelle system

**Liposomes**

Liposomes are phospholipid and cholesterol-based vesicles. Their nature is amphiphilic. medications that are hydrophilic can be delivered through the internal aqueous core, while hydrophobic medications are encapsulated in the phospholipid bilayer. Their blood circulation duration is prolonged when dextran or PEG is attached to the phospholipid bilayer, altering its surface. 32

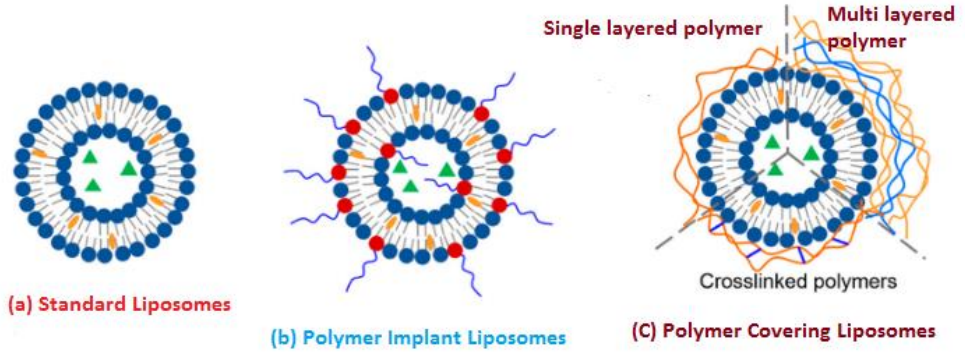


Fig: 15 Liposomes polymer system

**Implantable System**

The solid drug core is encircled by a permeable polymeric membrane in the majority of implants (drug delivery systems). Implants can be shaped into a variety of forms, including rods, discs, plugs, films, and pellets.[27] Depending on the polymer employed, the implants can be categorized as either biodegradable or non-biodegradable implants. Silicone, ethylene vinyl acetate (EVA), and polyvinyl alcohol (PVA) are the main polymers utilized in non-biodegradable implants. Depending on the grade and thickness of silicone utilized, it is possible to tailor silicone to be either an impervious or porous layer. Natural polymers including albumin, gelatin, and collagen, as well as synthetic polymers like polylactic acid, olyglycolic acid, and polylactic-co-glycolic acid (PLGA) copolymer, can be used to create biodegradable systems.

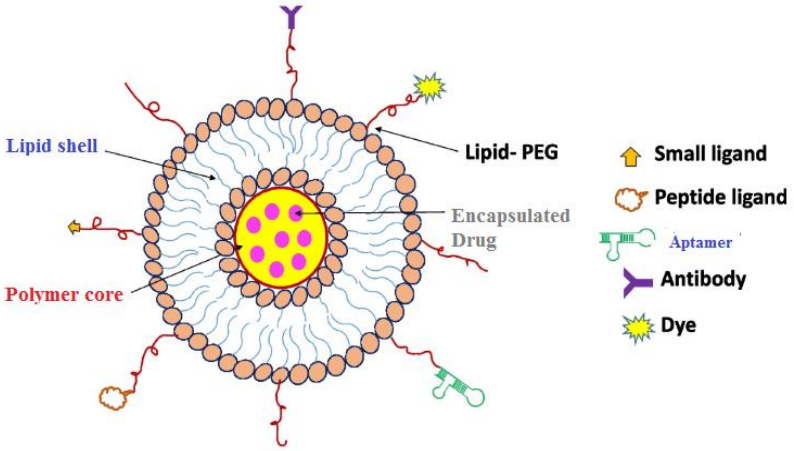


Fig: 16 Implantable polymeric system

## ADMINISTRATION SYSTEM OF POLYMER IN CONTROLLED DRUG DELIVERY

1. **Reservoir System:** A polymer film consisting of silicone, ethylcellulose, or polyethylene vinyl acetate encircles the drug core in these systems. The physicochemical parameters of the drug, the coating thickness, and the polymer's features all influence how quickly the drug releases its active ingredients. The medication is released by partitioning into the polymeric coat, diffusing into the outer coat of the polymer, and then entering the surrounding biological milieu.
2. **Occusert System**: medications are delivered to the eye via occusert systems, which are made of polymeric systems that improve the medications' ocular bioavailability and retention. Adjuvants in these systems are frequently polymers with high mucoadhesive qualities, such as Carbopol 934 P (cross-linked polyacrylic acids), which improve the drug's contact time with the absorbing mucosa by extending its residence duration in the eye. Thus, the therapeutic efficacy and drug absorption are improved. These methods work better than the traditional dosage, like eye drops that are quickly removed from the eyes by blinking or tears.
3. **Matrix systems:** This technique uses both hydrophilic and hydrophobic polymers to control and prolong the release of the medicine

once it has been dissolved or disseminated. Compared to hydrophobic polymers, hydrophilic polymers are more commonly utilized because of their strong gelling capabilities and ability to provide drugs the proper release characteristics. Water-insoluble polymer-containing matrix tablets enable the drug's slow release while remaining stable in the digestive system. The drug's slow breakdown from the poorly soluble therapeutic agent-polymer complex—such as methylcellulose, alginates, chitosan, and sodium carboxymethyl cellulose—causes this release.

4. **Biodegradable system:** After implantation, these polymers gradually break down in the biological environment. This is caused by the crosslinks that change the previously insoluble polymer into a soluble one to aid in removal, or by the hydrolysis of the primary polymer chain. One benefit of biodegradable polymers is that they can be broken down more quickly, saving the patient time and money by avoiding the need for additional surgery to remove the implant. In this system, polymers such as polylactic acid (PLA) and polyglycolic acid (PGA), as well as their copolymers like PGLA, are employed.
5. **Osmotically managed medication delivery methods**
   Osmotically controlled drug delivery systems: Osmotic pressure is used in oral osmotically controlled release delivery systems to regulate the active agent's administration. Although pH and other physiological parameters have little effect on drug release from these systems, it can be controlled by altering the characteristics of both the drug and the system. Since they expand when exposed to water and generate the pressure required for the drug's continuous release via the system's aperture, swellable polymers like vinyl acetate copolymer and polyethylene oxide are frequently used in systems.
6. **Temperature-sensitive medication administration**
   Drug delivery that is temperature-responsive: These controlled drug release devices release medication in response to changes in temperature. This is made possible by a specific class of polymers known as thermoresponsive polymeric systems. In these systems, copolymers of N-substituted acrylic and methacrylate amides, such as poly isopropyl acrylamide, are frequently employed. At body temperature, these polymers show reversible and temperature-dependent sol-gel transitions. This in turn regulates the rate of release and upholds the biological activity and physicochemical stability of the integrated medication.
7. **pH-responsive drug delivery**
   pH-responsive medication delivery: The pH levels in the gastrointestinal tract vary greatly, ranging from around one in the stomach to neutrality in the intestine. To enable controlled drug administration at a given time and spot, medicines targeting these regions are coupled with pH-responsive polymers. Tablets intended for the alimentary canal are coated with enteric polymers such as cellulose acetate butyrate and cellulose acetate phthalate. These polymers are soluble in less acidic gastrointestinal tract regions but insoluble in low pH conditions. To aid in drug absorption, the tablet and medication dissolve once the enteric coating melts. [33]

## CONCLUSION

Because polymers have a special strength in their application to drug delivery, new advances in the formulation of drug delivery systems that enhance therapy and treatment are made possible. One of the most significant applications of polymer technology is in pharmaceutical technology. The market and industry currently demand the discovery of new drug forms, such as new treatment systems and macromolecular prodrugs.Because of their toxicity and other drawbacks, using new polymers has advantages but also runs the risk of becoming detrimental. Choosing the right polymers is important when creating a distribution system. In order for the delivery systems to successfully complete the many stages of clinical trials and advance society, the ultimate objective is to provide biocompatible, less toxic, cost-effective, multifunctional, and biocompatible polymers.Thorough research in the fields of biomedical polymers and chemistry will also be necessary for the development of novel pharmaceutical and medical specimens. The remarkable progress in the polymerization of cyclic esters, ether-esters, and carbonates has been made possible by the use of natural compounds as initiators, catalysts, organo-catalysts, or coinitiators, as this discussion has also made clear. The molecules used are mostly safe, non-toxic, environmentally acceptable, and unique for the production of polymers used in medicinal applications.The primary objectives of this field at the moment are to facilitate and encourage additional research efforts aimed at competitive and translateable product development. A multidisciplinary and open-minded approach can lead to the swift and effective translation of developing polymeric drug delivery methods in the future.

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***CONFLICT OF INTERESTED***

The authors declare no conflicts of interest

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