



POLYMER: A BOON TO CONTROLLED DRUG DELIVERY SYSTEM

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ABSTRACT

Polymer plays a vital role in novel drug delivery systems with its longevity and self-transforming quality as excipient in tablet and capsule formulations. Use of polymer is now extended to controlled-release and drug-targeting systems. Polymers are obtained from natural sources as well as chemically synthesised. Polymers obtained from natural resources are used as such and also chemically modified for various applications. Polymers are classified as biodegradable and non biodegradable. The majority of biodegradable polymers used in controlled drug delivery undergo bulk erosion. In the present paper, classification of polymer along with their characteristics is given.

Keywords: Polymers, Matrix, Sustained Delivery, Solubility.

INTRODUCTION

Initially polymers were used as solubilisers, stabilizers and mechanical supports for sustained release of drugs. But over a period of time, the functionalities of polymers have changed. The polymers have been synthesized for specific needs and to solve specific problems associated with development of drug delivery systems. So there is need to understand the role of polymers.¹

Polymers can be classified based on the following categories and is shown in Table 1:¹

1. Source (Natural, semi synthetic, synthetic)
2. Type of polymerization (Addition, condensation polymers)
3. Chain growth polymerization (Free radical governed)
4. Degradability (biodegradable, non-biodegradable)
5. Nature of Polymer Water Interaction (hydrophobic polymer and water soluble polymer, hydrophilic polymer, hydrogel material)

TABLE 1. CLASSIFICATION OF POLYMERS

Based on Source	
Natural	Chitosan, Alginate, Gelatin, Albumin, Collagen, Dextran, Cyclodextrin, Polyethylene glycol (PEG).
Semi Synthetic	Hydroxy Propyl Cellulose (HPC), Methyl Cellulose (MC), Hydroxy Propyl Methyl Cellulose (HPMC), Hydroxy Ethyl Cellulose (HEC), Sodium Carboxy Methyl Cellulose (Na CMC).
Synthetic	Polyethylene, Polylactic acid, Polypropylene, Polyglycolic acid, Polyhydroxy Butyrate, Polyanhydride, Polyacrylamide
Type of Polymerization	
Addition Polymer	Polyethylene, Polypropylene, Polyvinyl Chloride,
Condensation Polymer	Polyester, Polyurethane
Chain Growth Polymerization	
	Polyethylene, Polystyrene, Polyacrylates
Degradability	
Biodegradable	Polylactic acid, Polyglycolic acid, Polycaprolactone, Polyanhydrides,
Non-Biodegradable	Polydimethyl Siloxane, Polyether Urethane, Ethyl Cellulose
Nature of Polymer Water Interaction	
Hydrophobic Polymer and Water Soluble Polymer	Ethyl Cellulose, Polydimethyl Siloxane.
Hydrophilic Polymer	Cellulosic: MC, HPMC, HPC, HEC, NaCMC. Non-cellulosic: Sodium Alginate, Xanthum Gum Carrageenan, Ceratonia (Locust Bean Gum), Chitosan, Guar Gum, Pectin, Polyethylene Oxide
Hydrogel Material	Cross-linked Polyvinyl Alcohol, Polyethylene Oxide, Polyacrylamide

Description of Polymers

Chitosan

Based upon the source Chitosan is a natural polymer. It has been extensively used in many areas ranging from food processing to waste management, medicine, biotechnology and pharmaceutical industries. Chitosan has been used widely in pharmaceutical applications as a formulation excipient as it is biodegradable, biocompatible and less toxic. It has been used as a mucoadhesive, oral absorption enhancer and in protein and gene delivery.¹

Alginate

Based upon the source Alginate is a natural polymer and are safe, non-immunogenic and inexpensive polymers with high mucoadhesive properties. Alginate is also used as thickener or emulsion stabilizer. Alginate microspheres can be used as a delivery system for antigens to mucosal surfaces. Excellent immune responses have been obtained by oral administration of alginate microparticles/microspheres, ranging in size from about 1 micron to more than about 30 microns. Alginate beads are used in site-specific oral delivery system for cationic therapeutic agents designed to target the agents to the

luminal side of the small intestine. The Alginate gel may contain a polymer coating such as poly-L-lysine to enhance stability and to add a positive charge to the surface.²

Gelatin

Based upon the source Gelatin is a natural polymer. It is also known as Byco, Cryogel etc. Gelatin can be used as coating agent, film-forming agent, gelling agent, suspending agent, tablet binder, viscosity-increasing agent. Gelatin is used as a biodegradable matrix material in an implantable delivery system. Gelatin is used for the microencapsulation of drugs, where the active drug is sealed inside a micro sized capsule or beadlet, which may then be handled as a powder. The first microencapsulated drugs (beadlets) were fish oils and oily vitamins in Gelatin beadlets prepared by coacervation. Low-molecular-weight Gelatin has been investigated for its ability to enhance the dissolution of orally ingested drugs. Therapeutically, Gelatin has been used in the preparation of wound dressings and has been used as a plasma substitute. Absorbable Gelatin is available as sterile film, ophthalmic film, sterile sponge, sterile compressed sponge, and sterile powder from sponge. Gelatin sponge has hemostatic properties.³

Albumin

Based upon the source albumin is a natural polymer. It is also known as Alba and chemically it's known as Serum Albumin. Human serum Albumin has a molecular weight of about 66500 and is a single polypeptide chain consisting of 585 amino acids. It can be used as stabilizing agent, therapeutic agent. Albumin is primarily used as an excipient in parenteral pharmaceutical formulations, where it is used as a stabilizing agent for formulations containing proteins and enzymes. Albumin has also been used to prepare microspheres and microcapsules for controlled drug delivery systems.⁴

Collagen

Based upon the source Collagen is a natural polymer and is one of the main components of many tissues in the body, and has been used for controlled drug delivery and tissue engineering applications, due to its biocompatibility and biodegradability and ease of gelation via physical or chemical cross-linking reactions. A number of chemical modification methods have been reported to improve the poor mechanical properties of Collagen matrices.⁵

Dextran

Based upon the source Dextran is a natural polymer. It can be produced by fermentation of media containing sucrose by *Leuconostoc mesenteroides*. Fractions of Dextran are readily soluble in water to form clear, stable solutions. They are also soluble in other solvents like Methyl Sulfide, Formamide,

Ethylene Glycol, and Glycerol. Dextran hydrogels can be obtained in various ways, based on either chemical or physical crosslinking. Dextran crosslinked with Methacrylate (MA), Hydroxy Ethyl Methacrylate (HEMA) has been used as hydrogel implants, microspheres for scaffolds. Carriers like Dextran, resulting in a stabilized enzyme preparation with longer circulation time and reduced immunogenicity.²

Cyclodextrin

Based upon the source Cyclodextrin is a natural polymer. It is chemically known as α -cyclodextrin, β -cyclodextrin, and γ -cyclodextrin. It can be used as solubilizing agent and stabilizing agent. Cyclodextrin is crystalline, nonhygroscopic, cyclic oligosaccharide derived from starch. Cyclodextrin can be used to form inclusion complexes with a variety of drug molecules, resulting primarily in improvements to dissolution and bioavailability owing to enhanced solubility and improved chemical and physical stability. Cyclodextrin inclusion complexes have also been used to mask the unpleasant taste of active materials and to convert a liquid substance into a solid material. β -cyclodextrin is nephrotoxic and should not be used in parenteral formulations. β -cyclodextrin is primarily used in tablet and capsule formulations.⁶

Polyethylene Glycol

Based upon the source Polyethylene Glycol is a natural polymer. It is also known as Carbowax. It is Chemically known as α -hydro-o-hydroxypoly (oxy-1,2-ethanediyl). It is represented by formula $H(OCH_2CH_2)_nOH$, where n is average number of repeating ethylene oxide groups. Polyethylene Glycols are family of water-soluble linear polymers formed by the additional reaction of Ethylene Oxide with Monoethylene Glycols or Diethylene Glycol. Polyethylene Glycol is stable, hydrophilic substance that is essentially non-irritant to the skin and its films are waxy, hygroscopic. The lower molecular weight grades of Polyethylene Glycol tend to be more appropriately used as plasticizers in aqueous film coating.⁷ Polyethylene Glycol is commonly mixed with hydrophobic polymers to regulate drug release owing to their excellent film-forming properties and solubility in organic solvents. It also has been found that a combination of Microcrystalline Cellulose and Polyethylene Glycol provides maximum protection from the damage of Potassium Chloride microcapsules by reducing interparticle friction. There are many grades of Polyethylene Glycol that represents them by their average molecular weight. For example, Polyethylene Glycol 400 consists of a distribution of polymers of varying molecular weights with an average of 400, which corresponds to an approximate average number of repeating Ethylene Oxide (EO) groups (n) of ≈ 9 . Chemical description of Polyethylene Glycol shown in table 2.⁸

TABLE 2: CHEMICAL DESCRIPTION OF POLYETHYLENE GLYCOL¹

Product	Chemical Description	INCI (CTFA) Name
PEG200	Polyethylene Glycol 200	PEG-4
PEG300	Polyethylene Glycol 300	PEG-6
PEG400	Polyethylene Glycol 400	PEG-8
PEG600	Polyethylene Glycol 500	PEG-12
PEG1000	Polyethylene Glycol1000	PEG-20
PEG1500	Polyethylene Glycol 1500	PEG-32
PEG4000	Polyethylene Glycol 40000	PEG-80

Hydroxy Propyl Cellulose

Based on source, nature of polymer water interaction, Hydroxyl Propyl Cellulose is classified as semisynthetic and hydrophilic polymer respectively. It is also known as Cellulose, Hydroxy Propyl Ether. It is chemically known as Cellulose, 2-Hydroxy Propyl Ether. It is non-ionic water-soluble and pH insensitive Cellulose Ether. It can be used in microencapsulation processes, transdermal patches and ophthalmic preparations and also used as thickening agent, tablet binding, controlled release and film coating polymer also commercially available in a number of different grades that have various solution viscosities with molecular weight 50000-1250000.⁹ The release rate of a drug increases with decreasing viscosity of Hydroxy Propyl Cellulose. The addition of an anionic surfactant similarly increases the viscosity of Hydroxyl Propyl Cellulose and hence decreases the release rate of a drug. Blends of Hydroxy Propyl Cellulose and other cellulosic polymers have been used to improve wet granulation characteristics and tableting characteristics, as well as to achieve better control and manipulation of the rate of drug release.⁹

Methy Cellulose

Based on source and nature of polymer water interaction, Methyl Cellulose is classified as semisynthetic and hydrophilic polymer. It is also known as benecel. Methyl Cellulose is used to produce sustained-release preparations.

Hydroxy Propyl Methyl Cellulose

Based on source and nature of polymer water interaction Hydroxyl Propyl Methyl Cellulose is classified as semisynthetic and hydrophilic polymer. Hydroxyl Propyl Methyl Cellulose used as the basis for sustained release hydrophilic matrix tablets. Hydroxyl Propyl Methyl Cellulose is an enteric film coating material or a matrix binder in solid dosage forms. 10-80% w/w of Hydroxyl Propyl Methyl Cellulose is used to retard the release of drugs from the oral delivery systems because of its non-toxic nature, easy compression, swelling properties and accommodation for high levels of drug.¹⁰ Addition of a soluble filler (i.e. Lactose) to Hydroxy Propyl Methyl Cellulose matrix systems increases porosity which leads to rapid diffusion of drug and also increases the rate of the polymer erosion which results in acceleration of drug release, addition of an insoluble filler (i.e. Calcium Phosphate Dihydrate) can inversely effect the release of drug from these systems dependent on its level.¹⁰ The performance of matrix tablets is strongly dependent on the matrix materials used, which are normally synthetic or semi-synthetic polymer. Depending on the properties of the polymer used, drug release from the tablets may be swelling-controlled, erosion-controlled, multiple mechanism controlled. Hydroxy Propyl Methyl Cellulose and Lactose combinations form an erodible hydrophilic gel matrix system. In hydrophilic matrix systems, the dissolution of the drug present at the surface of the matrix causes an initially high release rate of drug, followed by a rapidly declining drug release rate due to swelling and consequent increasing of the dissolution path-length of the matrix. To overcome this undesirable behaviour, various matrix geometries have been recommended to achieve an almost constant release rate of drug with time. One of these techniques relies on the use of multi-layered matrix tablets as a drug delivery device. Multi-layered matrix tablet is a drug delivery device, which comprises a matrix core containing the active solute and one, or more barriers (modulating layers) incorporated during the

tableting process. A three-layered matrix tablet consists of drug core layer sandwiched by the external modulating layers. The modulating layers which contain a hydrophilic polymer, usually Hydroxy Propyl Methyl Cellulose, delay the interaction of active solute with dissolution medium, by limiting the surface available for the solute release and at the same time controlling solvent penetration rate. Thus burst effect can be smoothed and the release can be maintained at a relatively constant level during the barrier layer's swelling and erosion process. When the swollen barriers are erosion dominated the surface available for drug release slowly increases. By this way, combining a time-dependent control of the hydration rate of the device with the reduction of tablet surface exposed to the dissolution medium, it is feasible to achieve a linear drug release profile. Some of the advantages of three-layered matrix systems include the maximum flexibility in drug release patterns, ease of manufacturing, total system solubility and total release of drug.¹⁰

Hydroxy Ethyl Cellulose

Based on source, nature of polymer water interaction Hydroxy Ethyl Cellulose is a semisynthetic and hydrophilic polymer. It is also known as Cellulose Hydroxy Ethylate. It is used as a thickening agent in ophthalmic and topical formulations, and also used as a binder and film-coating agent for tablets. It is present in lubricant preparations for dry eye, contact lens care, and dry mouth.¹¹

Sodium Carboxy Methyl Cellulose

Based on source and nature of polymer water interaction Sodium Carboxy Methyl Cellulose is a semisynthetic and hydrophilic polymer. It is also known as Sodium Cellulose Glycolate. It is chemically known as sodium salt of Carboxy Methyl Ether of Cellulose. It is an anionic water soluble polymer. Sodium Carboxy Methyl Cellulose has been used in blends with Hydroxyl Propyl Methyl Cellulose to prepare hydrophilic matrices. It is prepared from cellulose by treatment with alkali and monochloro-acetic acid or its Sodium salt. It can be used as thickening agent, stabilizer, suspending agent.¹⁰

Polyethylene

Based on source and type of polymerization Polyethylene is a synthetic and addition polymer respectively. Polyethylene is also known for chain growth polymerisation. Polyethylene is commonly used plastic matrix materials. It has been added to modify the drug-release pattern. Sustained-release tablets based upon an inert compressed plastic matrix were first introduced in 1960 and have been used extensively clinically. Release is usually delayed because the dissolved drug has to diffuse through a capillary network between the compacted polymer particles.⁸

Polylactic Acid

Based on source and degradability it is a synthetic and biodegradable polymer respectively. It is represented by a formula $(C_3H_4O_2)_n$. Entrapped drugs are released primarily by diffusion exhibiting an initial burst followed by a slowly decaying release rate for up to 100 days. Polylactic Acid or Polylactide show wide range of hydrophilicity which make them versatile in designing controlled release system. It can biodegrade under certain conditions, such as the presence of oxygen, and is difficult to recycle. Polylactide has been approved by the FDA for numerous clinical applications,

such as sutures, bone plates, abdominal mesh, and extended-release pharmaceuticals.¹² The implants containing bio-active agents in Lactide/Glycolide matrix are prepared by either solvent evaporation or injection molding technique. Solvent evaporation method is simple and suitable for thermolabile drugs but incomplete removal of solvent generally poses problems.¹³

Polypropylene

Based on source and type of polymerisation Polypropylene is a synthetic and addition polymer respectively. The use of plastic or polymeric material packages for tablets has become very popular, especially with unit-dose hospital packages for which aluminum foil is sometimes used. Polypropylene is commonly used polymeric materials to fit different shape and sizes of tablet packages.¹⁴

Polyglycolic Acid

Based on source and degradability Polyglycolic Acid is categorized under synthetic and biodegradable polymer respectively. It is the simplest linear, aliphatic polyester and known as a tough fibre forming polymer. It is represented by a formula $(C_2H_2O_2)_n$. Solubility of Polyglycolic Acid is dependent on the type and composition of monomer. It can be prepared starting from Glycolic Acid by means of polycondensation or ring-opening polymerization.¹³

Polyhydroxy Butyrate

Based on source Polyhydroxy Butyrate is a synthetic polymer. This polymer is biodegradable as well as bio compatible. The use of capsule Polyhydroxy Butyrate for controlled drug release. Polyhydroxy Butyrate is highly thermoplastic.¹⁵

Polyanhydride

Based on source and degradability Polyanhydride is a synthetic and biodegradable polymer respectively. Polyanhydride is investigated in an attempt to introduce polymeric system which can degrade only from surface to maximize control over release process. It is promising candidate which can erode in a controlled heterogeneous manner without requiring any additive.¹³

Polyester

Based on type of polymerisation it is a condensation polymer. A vast majority of biodegradable polymers studied belong to the polyester family. Among these Polyglycolic Acid, Polylactic Acid, and a range of their copolymers have historically comprised the bulk of published material on biodegradable Polyesters and have a long history of use as synthetic biodegradable materials in a number of clinical applications. These polymers have been used as sutures plates and fixtures for fracture fixation devices and scaffolds for cell transplantation.¹⁶

Polyacrylates

Polyacrylates comes under chain growth polymerisation. It is also known as Polyacrylic Acid and also Polyacrylates Elastomers. Polyacrylic Acid is a biodegradable water soluble polymer with various industrial applications, including as a super adsorbent (e.g., in disposable nappies), in water treatment, etc. The unique property of Polyacrylic Acid is that it exists as a liquid at pH 5 and as a gel at pH 7. Polyacrylic Acid based polymers are mainly used for oral and mucosal contact applications such as controlled release

tablets, oral suspensions and bio adhesives. It is also used as a thickening, suspending and emulsion stabilizing agent in low viscosity systems for topical applications. For bio adhesive applications, high molecular weight Acrylic Acid polymer crosslinked with Divinyl Glycol are extensively formulated in a variety of drug delivery systems for mucosal applications. Buccal, intestinal, nasal, vaginal and rectal bioadhesive products can all be formulated with such polymers.¹⁰ The function of Polyacrylamide in an extracorporeal toxin removal modality is to provide a support matrix for immobilization of the functional parts or ligands.¹⁰

Polyurethane

Polyurethane is a class of synthetic Elastomers which is used for a variety of medical implants, particularly for long-term implants. They have good biocompatibility. Since Polyurethane can be tailored to have a broad range of mechanical properties and good biocompatibility, there has been some interest to develop degradable Polyurethane for medical applications such as scaffolds for tissue engineering. However, a major problem has been the toxicity of degradation products, particularly those derived from the Di-Isocyanate component.¹⁶

Polycaprolactone

Based on type of polymerisation Polycaprolactone is a condensation polymer. It is hydrophobic, semi crystalline, biodegradable and nontoxic polyester. Its melting temperature is above body temperature (59-64°C), but its T_g is -60°C, so in the body the semi crystalline structure of Polycaprolactone results in high toughness, because the amorphous domains are in the rubbery state. Hydrolysis of Polycaprolactone yields 6-hydroxycaproic acid, which enters the citric acid cycle and is metabolized. Since Polycaprolactone degrades slowly it has been used in blends and copolymers with other biodegradable polymers. Polycaprolactone has been used clinically as a degradable staple for wound closure and as a 1-year drug delivery system for contraceptives. The amorphous regions of a semi crystalline polymer degrade prior to the crystalline domains, leading to a change in the release profile.²

Polydimethyl Siloxane

It is useful for water-soluble drugs and steroids for long acting drug delivery system such as sub dermal implant. It is represented by a formula $(C_2H_6OSi)_n$. Polydimethyl Siloxane is optically clear, inert, non-toxic and non-flammable. It is occasionally called Dimethicone. It is particularly known for its unusual flow properties and used in contact lenses and medical devices.¹⁷

Polyether Urethane

Based on the degradability it is non biodegradable polymer. Polyether Urethane is polymer composed of a chain of organic units joined by carbamate (urethane) links. Used in controlled drug delivery system. Polyether Urethane polymers are formed by combining two or several bi or higher functional monomers. One contains two or more Isocyanate functional groups (with formula $-N=C=O$) and the other contains two or more hydroxyl groups (with formula $-OH$). The alcohol and the Isocyanate groups combine to form a urethane linkage:

$$ROH + R'NCO \rightarrow ROC(O)N(H)R' \quad (R \text{ and } R' \text{ are alkyl or aryl groups}).$$

This combining process, sometimes

called condensation, typically requires the presence of a catalyst.¹

Ethyl Cellulose

Ethyl Cellulose chemically known as Cellulose Ethyl Ether. It is represented by a formula $C_{12}H_{23}O_6 (C_{12}H_{22}O_5)_n C_{12}H_{23}O_5$, where n can vary to provide a wide variety of molecular weights. Ethyl Cellulose can also be used as coating agent, flavouring agent, tablet binder, tablet filler, viscosity increasing agent. It is a non-toxic, stable, compressible, inert, hydrophobic polymer. Ethyl Cellulose can be used in sustained release products, including film coated tablets, microspheres, microcapsules and matrix tablets for both soluble and poorly soluble drugs.¹⁸ To modify the release of a drug, to mask an unpleasant taste, or to improve the stability of a formulation Ethyl Cellulose coating is generally used. Higher-viscosity Ethyl Cellulose grades produces stronger and more durable films. Ethyl Cellulose coated beads and granules have also demonstrated the ability to absorb pressure and hence protect the coating from fracture during compression. High-viscosity grades of Ethyl Cellulose are used in drug microencapsulation. Ethyl Cellulose produces hard tablets with low friability but show poor dissolution.¹⁹ Use of Ethyl Cellulose in sustained release products, including film coated tablets, microspheres, microcapsules and matrix tablets for both soluble and poorly soluble drugs. In non swelling matrix tablets the drug is embedded in a poorly soluble matrix such as Ethyl Cellulose or a Polymethacrylate. The combination of Ethyl Cellulose and a hydrophilic component such as Hydroxyl Propyl Methyl Cellulose offers a flexible system to tailor the drug release by changing the viscosity, substitution type and concentration of Hydroxyl Propyl Methyl Cellulose.²⁰ Ethyl Cellulose polymer coating is used for slow release of drug, the release is further slow down by the application of lipophilic plasticizer like Dibutyl sebacate.²¹ Ethyl Cellulose produces hard tablet with low friability, tablet usually will disintegrate readily drug dissolution will be impaired due to the fact that Ethyl Cellulose acts as an inert, hydrophobic matrix, however this can be advantageous for delaying release of water soluble drugs. Lower viscosity Ethyl Cellulose displays the slowest drug release rate, as this grade is more compressible and therefore has a lower porosity.²¹ Ethyl Cellulose is one of the most commonly used polymer for sustained release film coating. The polymer is insoluble, but permeable in water over the range of gastrointestinal pH, and thus can be utilized to produce semi-permeable membrane that controls the rate of drug release from coated substrate.²²

Sodium Alginate

Based upon the nature of polymer water interaction Sodium Alginate is a hydrophilic polymer. It is also known as Alginato Sodico. It is chemically known as Sodium Alginate. Sodium Alginate consists chiefly of the sodium salt of Alginic Acid. Sodium Alginate has also been used in the preparation of sustained-release oral formulations since it can delay the dissolution of a drug from tablets, capsules, and aqueous suspensions. Recently, Sodium Alginate has been used for the aqueous microencapsulation of drugs, in contrast with the more conventional microencapsulation techniques which use organic solvent systems. It has also been used in the formation of nanoparticles. The adhesiveness of hydrogels prepared from Sodium Alginate has been investigated, and drug release from oral mucosal adhesive tablets, buccal gels, and vaginal tablets based on sodium

alginate have been reported. The oesophageal bioadhesion of Sodium Alginate suspensions may provide a barrier against gastric reflux or site-specific delivery of therapeutic agents. Sponges composed of Sodium Alginate and Chitosan produce a sustained drug release and may be useful as wound dressings or as tissue engineering matrices.²³

Xanthum Gum

Based upon the nature of polymer water interaction Xanthan Gum is a hydrophilic polymer is a polysaccharide, derived from the bacterial coat of *Xanthomonas campestris*, used as a food additive and rheology modifier. It is represented by a formula $C_{35}H_{49}O_{29}$. It is a very effective thickener and stabilizer because it gives highly viscous solutions even at low concentrations as compared to other polysaccharide solutions. Xanthan Gum has also been used to produce directly compressed matrices that display a high degree of swelling due to water uptake, and a small amount of erosion due to polymer relaxation. It has also been used in combination with Chitosan, Guar Gum, Galactomannan, and Sodium Alginate to prepare sustained-release matrix tablets. Xanthan Gum has been used as a binder.²⁴

Carrageenan

Based upon the nature of polymer water interaction Carrageenan is a hydrophilic polymer. It is also known as Chondrus extract. It can be used as emulsifying agent, gel base, stabilizing agent, suspending agent, sustained-release agent, and viscosity-increasing agent. It is chemically known as Carrageenan, i-carrageenan, k-carrageenan, and l-carrageenan. Carrageenan can mask the chalkiness of antacid suspensions when used as a suspending agent. The inclusion of calcium or potassium salts into the tablet creates a microenvironment for gelation to occur, which further controls drug release. In combination with Chitosan, Agar and Polyvinyl Pyrrolidone, Carrageenan forms a water-insoluble complex which is able to absorb large amounts of body fluids, and is used as an effective wound dressing. Carrageenan is used in the preparation of hard and soft capsule shells.²⁵

Ceratonina (Locust Bean Gum)

Based upon the nature of polymer water interaction Ceratonina is a hydrophilic polymer. It is also known as Algarroba, St. John's bread. It is chemically known as Carob Gum. Ceratonina is a naturally occurring material generally used as a substitute for Tragacanth or other similar gums. As a viscosity-increasing agent, Ceratonina is said to be five times as effective as starch and twice as effective as Tragacanth. Ceratonina has also been used as a tablet binder and in oral controlled-release drug delivery systems.²⁶

Guar Gum

Based upon the nature of polymer water interaction Guar Gum is a hydrophilic polymer. It is also known as Galactosol, Guar flour. It is a galactomannan²⁶. It is primarily the ground endosperm of guar beans (*Cyamopsis tetragonoloba*) a plant of the leguminosae family. In solid -dosage forms it is used as a binder and disintegrant, in oral and topical products as a suspending, thickening, and stabilizing agent, and also as a controlled-release carrier. It has also been investigated in the preparation of sustained-release matrix tablets in the place of cellulose derivatives such as methylcellulose. Guar Gum based three-layer matrix tablets have been used experimentally in oral controlled-release formulations.²⁷

Pectin

Based upon the nature of polymer water interaction Pectin is a hydrophilic polymer. Pectin is a mixture of polysaccharides and is soluble in pure water. Pure and standardized pectin has been used as a binding agent in tablets. High Methoxy (HM) and Low Methoxy (LM) Pectin is used as monolithic bioerodible system, and to prepare beads by ionotropic gelation technique, sustained release drug delivery using Calcium Pectinate gel beads respectively. Film coated tablets can also be prepared using combination of HM-pectin and Ethyl Cellulose aqueous dispersion, HM or LM Pectin with Chitosan mixtures. Pectin also has several unique properties which have enabled it to be used as a matrix for the entrapment and/or delivery of a variety of drugs, proteins and cells. Pectin has been used as a thickening stabilizing and gelling agent stabilizer in food and beverage industry. It have been used in controlled-release matrix tablet formulations.¹

Polyethylene Oxide

Based upon the nature of polymer water interaction Polyethylene Oxide is a hydrophilic polymer. It is also known as Polyox. It is a non-ionic homopolymer of Ethylene Oxide. It is represented by the formula (CH₂CH₂O)_n, where n represents the average number of oxyethylene groups.²⁸ Polyethylene Oxide is used as matrix materials. High molecular weight Polyethylene Oxide successfully delayed

the release rate of soluble and insoluble drugs from matrix tablets prepared by direct compression. It is also used as a mucoadhesive polymer.²⁸

Cross-Linked Polyvinyl Alcohol

Cross-linked Polyvinyl Alcohol is a hydrophilic polymer. It also acts as hydrogel, this polymer is glassy in dehydrated state but in contact with water it swells and become elastic gel. Swelling behaviour of this hydrogel depends to the presence of salts and the degree to which the acetate groups are replaced by hydroxyl groups. The rate of drug release from hydrogel is regulated by cross-linking density and the extent of swelling; the entrapped drug with in the swelling matrix concomitantly dissolves and diffuses through the swollen network into surrounding aqueous environment. It has extensively been used in controlled release application. However, as this hydrogel is quite a hydrophilic system, it releases the drug with a relatively high rate.²⁹

Polyacrylamide

Polyacrylamide is a polymer formed from Acrylamide subunits. It can be synthesized as a simple linear-chain structure or cross-linked. It is represented by a formula (C₃H₅NO)_n. It is an important and hydrophilic polymer for preparation of hydrogels is a water-soluble polymer formed from Acrylamide subunits.³⁰

TABLE 3 REVIEW ON USE OF POLYMERS WITH VARIOUS DRUGS TO FORM SUSTAINED RELEASE FORMULATION

Drug	Polymer	Method
Atenolol	Xanthan gum, Guar gum	Direct compression method ³¹
Acetylsalicylic acid	Ethylcellulose, Eudragit RS100 and Eudragit S100	Direct compression method ³²
Aceclofenac	Hydroxy Propyl Methyl Cellulose K4M/K15M/K100M and 15CPS, Guar Gum, Ethyl Cellulose, Directly compressible Microcrystalline Cellulose (pH 102)	Wet granulation method ³³
Cefixime	Hydroxy Propyl Methyl Cellulose K100LV, K4M, K15M and K100M	Direct compression method ³⁴
Clarithromycin	Hydroxy Propyl Methyl Cellulose, Kollidan SR, Microcrystalline Cellulose, Ethyl Cellulose	Direct compression method ³⁵
Dexibuprofen	Hydroxy Propyl Methyl Cellulose, Xanthan Gum	Wet granulation method ³⁶
Diclofenac Sodium	Hydroxy Propyl Methyl Cellulose K15M, Microcrystalline Cellulose (MCC), Starch, and Lactose	Wet granulation method ³⁷
Furosemide	Guar gum, Pectin, Xanthan Gum	Direct compression method ³⁸
Indomethacin	Hydroxyl Propyl Methyl Cellulose k-100M, Starch, Ethyl Cellulose,	Wet granulation method ³⁹
Metformin Hydrochloride	Eudragit L-100 and S-100, Eudragit RLPO and RSPO	Direct compression method ⁴⁰

CONCLUSION

As per review of literature as shown in table no. 3 polymers hereby discussed in this article find a major concern in the manufacturing of matrix tablet and hence in controlled release formulations.

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