Available online on www.ijddt.com
International Journal of Drug Delivery Technology 2019; 9(1); 27-33
doi: 10.25258/ijddt.9.1.5

ISSN: 0975 4415

Review Article

Pharmaceutical Polymers - A Review

Naveen Kumar*, Sonia Pahuja, Ranjit Sharma

Swami Vivekanand College of Pharmacy, Banur-140601, Punjab, India

Received: 16th Oct, 18; Revised: 12th Jan, 19, Accepted: 12th Feb, 19; Available Online: 25th Mar, 2019

ABSTRACT

Humans have taken advantage of the adaptability of polymers for centuries in the form of resins, gums tars, and oils. However, it was not until the industrial revolution that the modern polymer industry began to develop. Polymers represent an important constituent of pharmaceutical dosage forms. Polymers have played vital roles in the formulation of pharmaceutical products. Polymers have been used as a major tool to manage the drug release rate from the formulations. Synthetic and natural-based polymers have found their way into the biomedical and pharmaceutical industries. Synthetic and Natural polymers can be produced with a broad range of strength, heat resistance, density, stiffness and even price. By constant research into the science and applications of polymers, they are playing an ever-increasing role in society. Diverse applications of polymers in the present pharmaceutical field are for controlled drug release. Based on solubility pharmaceutical polymers can be classified as water-soluble and water-insoluble. In general, the desirable polymer properties in pharmaceutical applications are film forming, adhesion, gelling, thickening, pH-dependent solubility and taste masking. General pharmaceutical applications of polymers in various pharmaceutical formulations are also discussed briefly.

Keywords: Polymers, Pharmaceutical polymers, copolymers.

INTRODUCTION

Polymers are used extensively in our daily routine life. "Polymer" word is derived from Greek roots "Poly" meaning many and "Meros" meaning parts. Polymers are long chain organic molecules assembled from many smaller molecules called as monomers. The word "polymer" means "many parts." A polymer is a large molecule made up of many small repeating units. Polymers are considered to be a subset of macromolecules. A *monomer* is a small molecule that combines with other molecules of the same or different types to form a polymer. If two, three, four, or five monomers are attached to each other, the product is known as a dimer, trimer, tetramer, or pentamer, respectively. An *oligomer* contains from 30 to 100 monomeric units. Products containing more than 200 monomers are simply called a polymer[1]. From the structural prospective, monomers are generally classified as functional (containing reactive functional groups) and olefinic (containing double bond).

Polymers symbolize a vital component of pharmaceutical dosage forms. It is acknowledged that the formulation and clinical performance of pharmaceutical dosage forms, e.g. solid dosage forms, implants, disperse systems, transdermal patches and particulate systems, is reliant on the physicochemical properties of the polymers used in the formulation. Pharmaceutical polymers represent a quite small proportion of the overall polymer sales. The Food and Drugs Administration, carefully control the standards of these polymers to make sure that no adverse effects result from their use[1,2].

History

The Swedish Chemist Berzelius first used the word polymer in 1833. Throughout the nineteenth century Chemists worked with macromolecules without having any clear understanding of their structure. Some modified natural polymers were, in fact, commercialized. Nitrated cellulose, for example, was marked under such names as celluloid and Guncotton. As long ago in 1839, the polymerization of styrene was reported. From the initial times, human has exploited naturally-occurring polymers as materials for preparing clothing, tools, weapons, decoration, shelter, writing materials and other necessities. The first semi-synthetic polymer ever made was guncotton (cellulose nitrate) by Christian F. Schonbein in 1845. The manufacturing process for this polymer has changed over the years due to its poor solubility, processability, and explosivity. In 1872, Bakelite, a strong and durable synthetic polymer based on phenol and formaldehyde, was invented. Polycondensation-based polymeric products such as Bakelite and those based on phenoxy, epoxy, acrylic, and ketones resins were used as cheap substitutes for many parts in the auto and electronics industries[3,6].

Classification

Based on origin

Natural Polymer: The polymers, which occur in nature are called natural polymer also known as biopolymers. e.g. Proteins – Collagen, Keratin, Albumin Carbohydrates – starch, cellulose, glycogen. DNA, RNA[4].

Synthetic Polymers: The polymer that was synthesized in the laboratory is known as a synthetic polymer. These are also known as artificial polymers. e.g. Polyesters, polyanhydrides and polyamides[4].

Author for Correspondence: bhardwajnaveen97@yahoo.com

Semi-synthetic polymer: These are natural chemically modified polymers, such as hydrogenated rubber, natural rubber, cellulose, cellulose nitrate, methyl cellulose, etc[4].

Based on Bio-stability

Bio-degradable Polymer

These polymers gradually disappears from the site of administration in response to a chemical reaction such as hydrolysis e.g. proteins, carbohydrates, polyesters etc[4].

Non – biodegradable Polymers

These are inert compounds and are eliminated intact from the site of application e.g. ethyl cellulose, HPMC, acrylic polymers, silicones[4].

Based on Reaction mode of Polymerization

Addition Polymers

They are produced from olefin, diolefin, vinyl and related monomers. These polymers are formed by the addition of monomeric molecules to one another in rapid succession by a chain mechanism. Examples of such polymers are polyethylene, polypropylene, polystyrene[4].

Condensation Polymers

They are formed by the intermolecular reaction between bifunctional and multifunctional monomeric molecules having reactive functional groups such as -OH, -COOH, -NH2, -NCO, etc[4].

Based on Interaction with Water

Hydrogels

They swell but do not dissolve when brought in contact with water. e.g. polyvinylpyrrolidone[4].

Soluble Polymers

These are moderate molecular weight uncross-linked polymers that dissolve in water. e.g. HPMC, PEG.[4]

Mechanism of Polymerization[5]

The linking together a large no of small molecule i.e. monomers with each other to form a macromolecule i.e. polymer through a chemical reaction is called polymerization. Other than compositional and structural differences between polymers Flory highlighted the extremely important difference in the mechanism of the polymer molecule to build up. The current terminology classifies polymerization into 'step polymerization' and 'chain growth polymerization[5].

Condensation Polymerization or Step-growth Polymerization

Condensation Polymerization is a chemical reaction in which polymer is produced and a small molecule of by-product with a lower molecular weight is released. The by-product eliminated is called as condensate. The reaction can take place between two similar or different monomers. It is also called as step-growth polymerization[5,6].

Addition Polymerization or Chain Polymerization

In addition polymerization, two or more molecules of monomers join together and form a polymer. In this polymerization, there is no removal of molecule. It is a chain reaction and no by-product is released. It is obtained by connecting together the monomer molecules by a chain reaction to produce a polymer whose molecular weight is exactly an integral multiple of that of the monomer as in the case of polyethylene obtained by polymerization of ethylene. A single monomer is involved in this polymerization and thus the polymer is homo-polymer and contains the same monomer units. The addition polymerization reaction is generally induced by light, heat or a catalyst to open the monomeric double bond and to create the reactive site[5].

Characteristics of Ideal Polymer[5]

It should be compatible with the biological environment, i.e. non-toxic and non-antigenic.

Should be easily administered.

Should be biodegradable or be eliminated from the body after its function is over.

Should be easy and inexpensive to fabricate.

Should provide drug attachment and release sites for drug-polymer linkages.

Applications of Polymers for The Formulation of Conventional Dosage Forms

Polymers are becoming important in the field of drug delivery. The pharmaceutical applications of polymers vary from their use as binders in tablets to viscosity controlling agents in liquids, emulsions and suspensions. Polymers can be used as film coatings to mask the obnoxious taste of a drug, to improve drug stability and to modify drug release characteristics[11].

Tablets

Tablets are the most commonly used dosage form for pharmaceutical preparations ment to be taken orally. Release of drug from the tablet can be controlled by altering the design and content of the formulation. In tablet the polymer are used as a Disintegrants and Binder. E.g. Starch, cellulose, Alginates, polyvinylpyrrolidine, sodium CMC etc are used as disintegrants. Polymers used as binders are Glucose, Starch, HPMC, Gelatin, Alginic acid, polyvinylpyrrolidine, Sucrose, Ethyl cellulose[4].

Polymers are also used to mask the unpleasant taste of the drug and also for enteric coating of tablets e.g. Shellac and zein[9,10].

Capsules

Capsule consists of a dose of drug enclosed in a water-soluble shell or envelope. Capsules are used for oral medication consisting of the drug and a suitable dispersion medium enclosed in a flexible gelatin shell. The polymers are used in the capsule as a plasticizer on which the strength and flexibility of the gelatin depend.The drug release rate of the Capsule is controlled by using the several type of polymer[4].

Polymers in Parenteral

In Parenteral the various polymer like Methacrylic acid act as an Interferon inductor which induce to the interferon in cancer like disease. Methacrylic acid alkyl amide is act as plasma expander which increase the plasma level in body when admixture of drug with polymer present in body. Some Vaccines are transpired by using polymer because which disintegrate in GIT tract, example Methyl methacrylate[14].

Polymers in Disperse systems

The term "Disperse System" refers to a system in which one material is distributed, in discrete units, throughout a second substance (the continuous Phase). Each phase can exist in solid, liquid, or gaseous state. Suspensions, emulsions, colloids, pastes and ointments are some of the examples for disperse systems. Polymers used in these

systems include polyvinyl pyrolidone (PVP), polyethylene glycol (PEG), sodium carboxymethyl cellulose, carbopol, acacia, sodium alginate, methylcellulose, polymeric surfactants etc[6].

Polymer in Transdermal Drug Delivery Systems (Patches)

In the formulation of Transdermal Patches various polymer are used. The baking material is also prepared from the polymer to support the drug in the drug reservoir[8].

Polymers in Gels as dosage forms

A gel is a soft, solid or solid-like material consisting of two or more components, one of which is a liquid, present in substantial quantity. The term "hydrogel" was introduced by Thomas Graham in 1864 to denote silicic acid hydrates with gelatinous properties. Gelation occurs via the cross-linking of polymer chains. Some examples of polymers used here are poly (acrylic acid) polymers with the proprietary names carbopol, deacetylated gellan gum, carboxymethylcellulose, methylcellulose etc.

Polymers for coatings of solid dosage forms

The use of coatings on drugs was probably an adaptation from early food preservation methods. Coating of solid dosage form is done to mask the taste of medicines. Sugar coating, color coating, film coating and enteric coating are the different coatings done for solid dosage forms. Sugar coating process involves several steps[9].

The basic sugar coating process involves the steps like sealing, subcoating, syrupying, finishing and polishing. Shellac a natural polymer, is an effective sealant. Polishing utilizes powdered wax like beeswax or carnauba wax. As the sugar coating process was very time consuming, in order to increase the productivity, film coating process was developed. Polymers like hydroxypropylmethyl cellulose, ethylcellulose, sodium carboxy- methylcellulose, povidone, propylene glycol, polyethylene glycol, cellulose acetate phthalate etc., are used as film former for film coating[9,10].

Enteric coating of pills and compressed tablets has existed for more than a century. The reasons for enteric coatings are to protect acid-liable drugs from the gastric fluid, to prevent gastric discomfort or nausea due to irritation from a drug, to deliver drugs intended for local action in intestine etc.. Polymers like cellulose acetate phthalate, acrylate polymers, hydroxypropylmethylcellulose phthalate, and polyvinyl acetate phthalate are few examples[9].

Chitosan's film forming abilities lend itself well as a coating agent for conventional solid dosage forms such as tablets. Furthermore its gel- and matrix-forming abilities make it useful for solid dosage forms, such as granules, micro particles, etc. Crystallinity, molecular weight, and degree of deacetylation were seen to be factors that affected the release rates from the chitosan-based granules. Combination of positively charged chitosan with negatively charged biomolecules, such as gelatin, alginic acid, and hyalouronic acid, has been tested to yield novel matrices with unique characteristics for controlled release of drugs[14,15].

Applications in Controlled Drug Delivery

Over the past few decades an interest has developed in the design and formulation of dosage forms that control the subsequent release of drug from the dosage form into the surrounding biological fluids. Consequently, this rate process effectively controls the pharmacological properties of the therapeutic agent. Central to the development of such systems is role of pharmaceutical polymers. In light of the current and continuing importance of this category of drug delivery system the following section provides a concise overview of the range of designs of controlled release drug delivery systems and the contribution/significance of polymers to their function. Following administration, the drug is absorbed into the systemic circulation in a stepwise fashion involving[7]:

Drug diffusion through the matrix of the dosage form.

Drug dissolution within the aqueous fluid of the gastrointestinal tract.

Drug diffusion through the aqueous fluid of the gastrointestinal tract to the surrounding tissue, e.g., the villi of the small intestine.

Absorption of the drug across the wall of the gastrointestinal tract.

Entry into the systemic circulation and deposition at the required site of action

Following are the various controlled delivery systems[7]

Reservoir Systems

In these systems, the core containing the drug is separated from the biological fluids by a water insoluble coating or polymer layer. Examples of polymers which are usually used as polymeric coatings include poly (ethylene vinyl acetate), silicone, ethyl cellulose and various acrylate copolymers. The drug release from these systems occurs by a number of steps, firstly involving the partitioning of the drug into the polymeric coat. The drug then diffuses from the inner to the outer side of the coat/layer due to the difference in concentration gradient and at this stage partitions into the surrounding biological media[7,12].

The Ocusert System

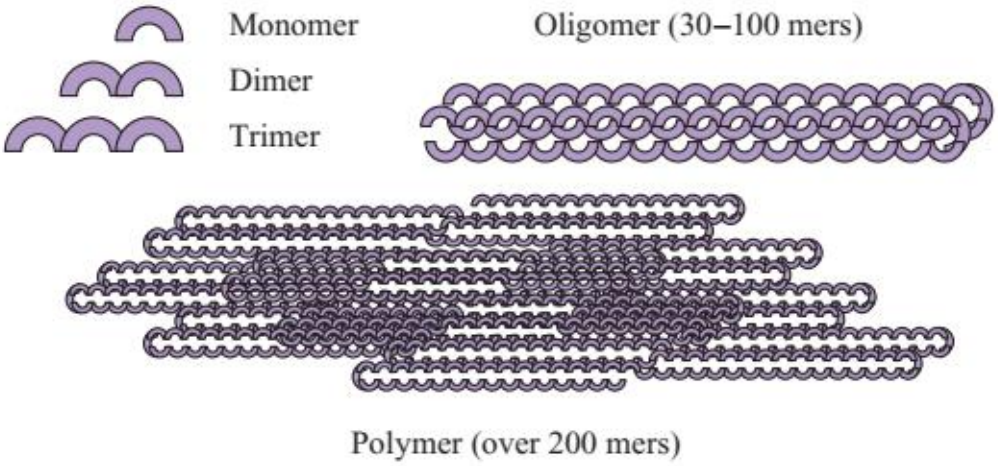
The delivery of therapeutic agents to the eye for the treatment of disorder of the eye (e.g. glaucoma). Using conventional drug delivery systems, e.g., drops, ointments, is an inefficient process. This is primarily due to the rapid clearance of drugs from the surface of the eye due to blinking and tears flow. One method by which the efficiency of ocular drug delivery may be improved is through the use of polymeric implants that are implanted under the lower cul-de-sac of the eye[7,12].

Matrix Systems

In matrix designed drug delivery systems, the drug is homogeneously dispersed, either at the molecular scale or as solid particles, within a polymeric medium. In comparison to reservoir systems, the manufacture of matrix designed drug delivery systems is simpler. Matrix drug delivery devices are composed of drug that is either dissolved or dispersed within a polymeric matrix. Diffusion of the drug through the polymeric matrix is the rate-controlling step and thus is responsible for the resulting pharmacological properties[7].

Biodegradable Systems

Biodegradable systems are those in which a therapeutic agent has been incorporated into a matrix that is composed of a biodegradable polymer, i.e., a polymer that will



undergo controlled degradation within a biological environment. As a result, following implantation, the molecular weight of the polymer matrix will be reduced for example, hydrolysis of crosslinks or hydrolysis of the main polymer chain, and in so doing the previously insoluble polymer matrix will be rendered soluble in the biological fluids thereby facilitating elimination. There are several examples of biodegradable polymers that have been examined for controlled release applications. These include poly(lactic acid), poly(glycolic acid) and their copolymers poly(*ortho* esters) and polyanhydrides[7,12].

Osmotically Controlled Drug Delivery Systems

In these systems the difference between the osmotic pressure within a formulation and the surrounding biological fluids is used as the driving force for drug release. The first osmotically controlled drug delivery systems were composed of two primary regions, namely a tablet core (containing the drug and when required an osmotic pressure modifier) and a semi-permeable membrane. The general mechanism of drug release from these systems involves the diffusion of gastrointestinal fluid across the semi-permeable membrane at a controlled rate and dissolution of the drug and, if present, the osmotic pressure modifier to produce a saturated drug solution within the tablet core[7,12].

Temperature Responsive Drug Release

Several reports have been published on the design and application of controlled systems for the administration of drugs that use the temperature as an external stimulus. The polymers used to obtain such release properties are referred to as thermoresponsive polymeric systems. Typically, the homo and copolymers of N-substituted acrylic and methacrylate amides [e.g. poly (isopropyl acrylamide)], are used for this purpose. More specifically, there are two types of thermoresponsive polymer systems namely those that exhibit positive and negative temperature dependency. Polymers in the former category display an upper critical solution temperature below which polymer contraction occurs upon cooling. Conversely, negative temperature dependent polymers have a lower critical solution temperature and will contract upon heating above the lower critical solution temperature[6,7].

pH Responsive Drug Release

In the design of dosage forms, a specific goal may be to obtain the release of the drug in the sites that guarantee maximum therapeutic benefits. Within the gastrointestinal tract a range of pH values exist, ranging from about one in the stomach to neutrality within the intestine. Targeting drug release within certain regions of the gastrointestinal tract as a method to enhance drug stability within acidic fluids or to reduce the irritant effects of certain drugs has been used for several decades. For example, enteric polymers have been used as tablet coatings for this purpose, examples of which include cellulose acetate phthalate and cellulose acetate butyrate. These polymers are insoluble in low pH environments; however they are soluble in the less acid regions of the gastrointestinal tract. Following dissolution of the enteric coating, the tablet and hence the drug will dissolve, thereby facilitating drug absorption. Due to this pH dependent solubility, enteric polymers may be described as pH responsive polymers[6,7].

Swelling Controlled Release Systems

In many drug delivery systems, the dimensions of the dosage form will change during the course of drug release due to swelling of the polymer matrix. Although the mechanism for drug release is diffusion, Examples of systems that exhibit swelling controlled release are physically crosslinked and chemically crosslinked gels. In terms of controlled drug release, chemically Crosslinked hydrogels e.g., poly(hydroxyethylmethacrylate), have been used to provide controlled drug release from medical devices, whereas swelling controlled physical hydrogels may be easily manufactured by directly compression of drug with a hydrophilic polymer, e.g., HPMC[7,12].

Application in Manufacturing

Many polymers are used as packaging materials for pharmaceutical products. The properties of the plastic packaging materials, such as gas permeability, flexibility, and transparency, are responsible for specific applications. Flexible packages are made by the use of thin and flexible polymer films. The thin, flexible films are usually produced from cellulose derivatives, Poly(vinyl chloride) (PVC), polyethylene, polypropylene, polyamide (nylon), polystyrene, polyesters, polycarbonate, poly(vinylidene chloride), and polyurethanes. These polymeric materials

Pharmaceutical Applications[16]

Polymer	Uses
Poly (ethylene oxide)	Coagulant, flocculent, very high molecular-weight up to a few millions, swelling agent
Poly (vinyl pyrrolidone)	Used to make betadine (iodine complex of PVP) with less toxicity than iodine, plasma replacement, tablet granulation
Poly (vinyl alcohol)	Water-soluble packaging, tablet binder, tablet coating
Polyacrylamide	Gel electrophoresis to separate proteins based on their molecular weights, coagulant, absorbent
Carboxymethyl cellulose	Superdisintegrant, emulsion stabilizer
Hydroxypropyl methyl cellulose	Binder for tablet matrix and tablet coating, gelatin alternative as capsule material
Cellulose acetate phthalate	Enteric coating
Alginic acid	Oral and topical pharmaceutical products; thickening and suspending agent in a variety of pastes, creams, and gels, as well as a stabilizing agent for oil-in-water emulsions; binder and disintegrant.
Chitosan	Cosmetics and controlled drug delivery applications, mucoadhesive dosage forms, rapid release dosage
Sodium starch glycolate	Superdisintegrent for tablets and capsules in oral delivery
Polycyanoacrylate	Biodegradable tissue adhesives in surgery, a drug carrier in nano and microparticles
Silicones	Pacifier, therapeutic devices, implants, medical grade adhesive for transdermal delivery

are generally heat sealable and are also capable of being laminated to other materials[2].

Polymers are used in manufacturing of following

Bottle

Vials

Syringes surgical devices

Supporting materials e.g., prostheses and sutures

Materials for orthopedics applications.

Rubber closures

rubber and plastic tubing for injection sets

Barrels and plungers of hypodermic syringes

Current Status and Future Prospects Of New Drug Delivery System

With the progress in all spheres of science and technology, the dosage forms have evolved from simple mixtures and pills to the highly sophisticated technology intensive drug delivery systems, which are known as Novel Drug Delivery Systems (NDDS). Quest for New Drug Delivery System (NDDS) has got new impetus since early eighties to have improved therapeutic outcome from the same drug, because the NDDS have several advantages over the conventional dosage form. Since then several NDDS have been developed and it constitute a sizable portion of the global market. Indian researchers have shifted their interest towards NDDS since early eighties[16].

Types of Novel Drug Delivery Systems

There are multiple schemes of classification of types and techniques of NDDS - based on therapeutic group of drugs loaded, physical form, intended application route, mechanism of delivery or action, etc. and none would be complete[16].

Microparticulate Drug Delivery Systems

Drugs encapsulated within polymeric beads in order to control the release, mask taste, prevent degradation from atmospheric moisture and to ensure proper delivery as desired. These multi-unit dosage forms are mainly intended for oral delivery, though parenteral and other routes of administration have also found commercial and clinical success. Different systems implement various rate controlling mechanism including nonerodible mechanical barrier for diffusion controlled release, microporous membrane systems, water swellable and hydrogel systems, pH sensitive polymer coated systems, gastric floatation systems, mucoadhesive systems, colon-specific delivery systems, etc. a large spectrum of drug have been modulated for release and other properties, e.g. cardiovascular drugs, antipsychotics, antibacterial and chemotherapeutic agents. The selection of polymer for a particular multiparticulate system is crucial and a wide variety of polymers such as cellulose derivatives (methyl, ethyl, hydroxypropyl, hydroxypropyl methyl cellulose), acrylic polymers, biodegradable polymers (Polylactide coglycollic acid, poly lactic acid, polyglycollic acid, etc.) and natural polymers (sodium alginate, albumin, other proteins, chitosan, etc.) are used depending on the requirement of the particular system to be developed[15,16].

Nanoparticles

These are colloidal drug delivery systems in the nanometer size range having wide application potential at present. They have got all characteristics of the liposomes minus the stability problems. They have been utilized to deliver and control the release of drug molecules from suitable polymeric nanoparticles/ nanospheres. Usually FDA approved biocompatible polymers such as poly (L-lactide - D-glycollic acid) have been used, though other polymers such as polyepsilon-caprolactone, chitosan and polyalkyl cyanoacrylates have been also used. Their most promising area of application is tumor targeting capability. Nanoparticles are not only suitable for parenteral administration, but also they have been exploited as advanced systems for drug delivery through cornea, skin, bronchioles and oral routes[15,16].

Osmotically Modulated Drug Delivery Systems

A very successful form of NDDS is the osmotic systems, usually, tablets coated with semi-permeable barrier polymers that has a laser-drilled precision hole as drug delivery orifice. In the gastrointestinal fluid the osmotic materials inside the tablets cause increase in osmotic

pressure inside the barrier which forces drug to rush out of the orifice at a predetermined rate[15,16].

Aquasome

These are carbohydrate stabilized nanoparticles of ceramics / calcium phosphate having water-like properties that help to protect and preserve the fragile biological molecules. They are comprised of a solid nano-crystalline core coated with oligomeric film to which the drug moieties or biochemically active molecules are adsorbed with or without modification. There three layered structures are self assembled by non-covalent and ionic bonds. Their intended route of administration is parenteral and with advancement of research in this field, other routes might be contemplated[15,16].

Dendrimers

In search for novel biomaterials for controlled and targeted delivery of bioactives, Starburst Dendrimers are the latest stars that bear promising properties for the delivery of drugs, vaccine, metals or genes to the desired sites. In spite of being polymers they bear similarity with vesicular structures such as micelles, liposomes and globular proteins. The dendrimers are three-dimensional branched structures like trees and hence the name "Dendrimer". They possess a very large number of chain ends and synthesized chemically. Into the branches of dendrimers drugs and other biologically active molecules could be entrapped for controlled and/or targeted delivery initially via parenteral route and subsequently other routes could be tried[15,16].

Multiple

These are emulsions of emulsions in which the internal phase consists of dispersed globules, which are made of a simple (two-phase) emulsion. There are two types - oil/water/ oil or water/oil/water, i.e., two similar phases separated by an immiscible phase, which is sometimes called liquid membrane that acts as a semipermeable membrane for drug molecules to diffuse through it at a controlled rate. A promising use of multiple emulsions is drug targeting via antibody / ligand tagging to the carrier droplets. Also, because of their globular size drugs may be targeted to lungs and reticulo endothelial systems (RES). The techniques of multiple emulsions formulation has also been used to prepare micro- and nano-particles for controlled and targeted drug delivery[15,16].

Microemulsions

Microemulsions are transparent thermodynamically stable systems of colloidal nature that are formed from classical emulsions, but at specific phase-volume ratios. They afford solubilization of water-insoluble molecules, thereby improving their bioavailability as well as applicability and reduced ADME problems. A widely used immunosuppressant, Cyclosporin, have been formulated commercially as a microemulsion for increased solubility and bioavailability. Proteins and peptides may also be formulated as oral microemulsions, such as oral insulin systems, and also scope exists in developing oral vaccines through this system[15,16].

Liposomes

These are uni-/multilamellar phospholipid vesicles composed of concentric spherical layers of aqueous zones sandwiched between phospholipid membranes. Both water and oil soluble drugs can be encapsulated in the liposomes either in the aqueous zone or the lipid-bilayers according to their solubility. They are often referred to as "artificial cells" as they resemble one in almost all practical aspects. They showed immense potential in delivery of anti-tumor therapeutics as well as anti-fungals. Drugs such as Amphotericin B, Doxorubicin and Daunorubicin have been successfully launched in market as liposomes[15,16].

Niosomes

These are vesicles like liposomes, but made up of non-ionic surfactants and like liposomes. They can also entrap hydrophilic as well as lipophilic drugs. They have better stability than liposomes and hence have greater interest for industrial adoption. The non-ionic surfactant systems make niosomes inherently target-specific to tumor, liver and brain. They have been reported to be useful as targeting systems of drugs for treatment of cancer and in therapy of microbial diseases caused particularly by virus and parasites. Tumor targeting of Methotrexate in mice model have been highly successful. Since no special handling / storage precautions are required for niosomes, their commercial exploitation would be easier. They are biodegradable and reduce systemic toxicity of various antitumor and antimicrobial agents by localizing the drug to specific sites of action[15,16].

CONCLUSION

Researchers all over the world are trying to find ways of enhancing the therapeutic efficiency of drugs by changing the formulation technique, polymeric systems, *etc.* The limitation of the traditional dosage forms has been overcome by using polymers, synthesized especially to solve the problems. The utilization of novel polymers offers benefits beside they can also to be harmful because of the toxicity and few incompatibilities related with them. Proper care should be taken while selecting polymers for a delivery system. The vital goal is to establish biocompatible, multifunctional, less toxic polymers, cost-effective delivery systems.

REFERENCES

1. Gowariker VR, Viswanathan NV and Shreedhar (2005) J. Polymer Science, New Age International, New Delhi.
2. Narendra Pal Singh Chauhan , Arpit Kumar Pathak , Kumudini Bhanat , Rakshit Ameta , Manish Kumar Rawal , Pinki B. Punjabi . Pharmaceutical Polymers. In Encyclopedia of Biomedical Polymers and Polymeric Biomaterials. Taylor and Francis: NewYork, Published online: 27 Jan 2016; 5929-5942.
3. Van Savage, G. and Rhodes, C.T., The sustained release coating of solid dosage forms: a historical review, Drug Dev. Industrial Pharm., 21(1), 1995, 93.
4. Flory PJ (1997) Principles of Polymer Chemistry. Sixteenth Printing, Cornell University Press, New York.
5. Odian George (2004) Principles of Polymerization. Fourth Edition. Wiley International,Jersey,USA.

6. Taylor and Francis, Polymers in Drug Delivery System, 2006, 1-236
7. Jones David. (2004). Pharmaceutical Applications of Polymers for Drug Delivery. Rapra Technology Limited. Page no 16-37.
8. Kiran Sharma, Natural biodegradable polymers as matrices in transdermal drug delivery, Int. J. Drug Dev. & Res., April- June 3 (2): 2011, 85-103.
9. Singh Deep Hussan, Roychowdhury Santanu, Verma P., B. V. (2012). A review on recent advances of enteric coating. IOSR Journal of Pharmacy, 2(6), 05-11.
10. Chanda M (2006) Introduction to Polymer Science and Chemistry. CRC Press, Taylor and Francis Group, FL, USA.
11. Reja M, Quadir MA, Haider SS, Comparative evaluation of plastic, hydrophobic and hydrophilic polymers as matrices for controlled release drug delivery, J Pharm Sci 692, 2003, 274-291.
12. Longer, M.A., Chung, H.S., and Robinson, J.R., Bioadhesive polymers as platforms for oral controlled drug delivery III: oral delivery of chlorothiazide using a bioadhesive polymer, J. Pharm. Sci., 74(4), 1985, 406.
13. Piringer OG, Baner AL (1977) Plastic Packaging: interaction with food and pharmaceutical. 2nd Edition, Wiley-VCH Verlag GmbH, Weinheim. Furuta M.
14. http://www.pharmachitchat.com/review-on-applications-of-polymers-in-pharmaceutical-formulations.
15. Tiwari R, Prakash AR, Shukla S and Pandey A:Controlled drug release for poorly water soluble drugs- a role of polymeric nanoparticles. *Int J Pharm Sci Res* 2014; 5(5): 1661-70.doi: 10.13040/IJPSR.0975-8232.5 (5).1661-70.
16. Subhash Mandal, C. M. (2010). Status and Future Prospects of New Drug Delivery System. Pharma Times , 42 (4), 13-16.