Open Access Review Article

ISSN: 2349-9818
January - February 2025, Vol. 12 (1), 33-44

Tropical Journal of Pharmaceutical and Life Sciences
(An International Peer Reviewed Journal)
Journal homepage: http://informativejournals.com/journal/index.php/tjpls

POLYMERIC NANO-CARRIERS FOR DRUG DELIVERY SYSTEMS IN CANCER THERAPY - AN EXHAUSTIVE REVIEW

J Pavan Kumar*[1], Ranjan Kumar Singh[2], Chennu MM Prasada Rao[2], Rajeswari Tanniru[2] and Ajay Garg[2]

[1]Research Scholar, School of Pharmacy, Raffles University, Neemrana, Raj-301705.

[2]Faculty School of Pharmacy, Raffles University, Neemrana, Raj-301705.

ARTICLE INFO:

Received: 11th Jan. 2025; **Received** in revised form: 27th Jan. 2025; **Accepted:** 15th Feb. 2025; **Available online:** 27th Feb. 2025.

Abstract

Progress in molecular pharmacology and a better comprehension of the mechanism of various diseases have necessitated the precise targeting of the cells responsible for initiating and advancing these diseases. This is particularly applicable to the majority of life-threatening illnesses that necessitate treatment medicines with multiple adverse effects. Therefore, precise tissue targeting is necessary to minimize systemic exposure. Modern drug delivery systems (DDS) are developed utilizing cutting-edge technology to expedite the administration of drugs across the body to a particular target area, optimizing the effectiveness of the treatment and reducing the buildup of drugs in unintended areas of the body. Consequently, they significantly impact the management and treatment of diseases. Modern drug delivery systems (DDS) provide significant advantages over traditional methods. These include improved performance, automation, precision, and efficacy. They consist of nanomaterials or miniaturized devices that comprise multifunctional components. These components are biocompatible, biodegradable, and possess high viscoelasticity, resulting in a longer circulating half-life. This article thoroughly examines the history and technological progress of medication delivery systems. The text provides an update on the latest advancements in drug delivery systems, including their therapeutic applications used in Cancer, their present obstacles, and potential future improvements for enhanced performance and utilization.

Keywords: Drug delivery systems, Nanoparticles, Nanocarriers, Tumor, Chemotherapy, Pharmacokinetics.

Introduction

When viewed from a different angle, drug delivery systems can be understood as channels through which therapeutic chemicals are introduced into the body. Chewing the leaves and roots of medicinal plants and inhaling the soot that is produced when medicinal items are burned are two examples of medication delivery methods that have been used since the beginning of time. The distribution of medications using these rudimentary methods, on the other hand, did not meet a very fundamental requirement in drug delivery, which was the requirement for consistency and uniformity (a required drug dose). The latter half of the eighteenth

***Corresponding Author:**
J Pavan Kumar

DOI: https://doi.org/10.61280/tjpls.v12i1.176

century and the early nineteenth century saw the emergence of a variety of approaches to the administration of drugs as a result of this. Pills, syrups, capsules, tablets, elixirs, solutions, extracts, emulsions, suspensions, cachets, troches, lozenges, nebulizers, and a wide variety of other conventional delivery mechanisms were among the several methods that were utilized. Drugs that are derived from plant extracts are utilized by a significant number of these delivery systems.

The advent of modern medicine commenced with the identification of vaccinations in 1885 and the development of methods for refining medicines from botanical origins in the late 19th century. Subsequently, the introduction of penicillin ensued after its discovery in 1929, marking the commencement of a subsequent age of extensive pharmacological exploration. The genetic modification of microorganisms, which are subsequently converted into drug-producing facilities, is an essential stage in the development and production of a diverse range of pharmaceutical treatments. Examples of anti-cancer drugs include recombinant deoxyribonucleic acid (DNA), human insulin, interferon (used to treat acquired immunodeficiency syndrome (AIDS) related Kaposi's sarcoma, Hairy cell leukemia, Hepatitis B and C, and other carcinomas), interleukin-2 (used to treat renal cell and other carcinomas), erythropoietin (used to treat anemia associated with chronic renal failure/AIDS/antiretroviral agents, chemotherapy-associated anemia in amyloid malignancy patient), and tissue plasminogen activator. What was once a mere aspiration, the ability to regulate and innovate drug administration has now become a tangible achievement. Pharmaceutical and other scientists have thoroughly investigated this subject of drug research for the past 15 years.

Drug carriers encompass a variety of substances such as soluble polymers, insoluble or biodegradable microparticles, natural and synthetic polymers, microcapsules, cells, cell ghosts, lipoproteins, liposomes, and micelles. It is possible to construct carriers that are slow to degrade, responsive to stimuli such as changes in pH or temperature, and tailored to specific locations. The process of guiding the drug-loaded system to a certain place is referred to as targeting.[1]

Different kinds of drug delivery systems-

- Oral medication delivery,
- nasal drug delivery,
- and ocular drug delivery.
- Drug administration by oral mouth.
- Pulmonary medication delivery systems are also available.
- Sublingual drug delivery system.
- Transdermal drug delivery system.
- Vaginal drug delivery system.

Recently, several drug delivery systems (NDDS) have been developed using advanced systems for more convenient, controlled, and targeted delivery. Each drug delivery system has its peculiarities that determine its release rate and mechanism. This is largely due to the differences in the physical, chemical, and morphological characteristics which will ultimately affect their affinities for various drug substances.[2] Furthermore, the current advancements in producing substantial quantities of oligonucleotide, peptide, and protein pharmaceuticals have made gene therapies appear to be feasible for therapeutic purposes. A specialized drug delivery system is essential for the correct administration of each medicinal material due to factors such as its size, stability, or the need for targeted distribution. Complex delivery systems must consider pharmacokinetic principles, specific drug characteristics, and the variability of response among individuals and within the same individual under different conditions. Examples of anti-cancer drugs include those used for the treatment of conditions such as immunodeficiency syndrome (AIDS) related to Kaposi's sarcoma, Hairy cell leukemia, Hepatitis B and C, and other carcinomas, as well as drugs like interleukin-2 (used for renal cell and other carcinomas), erythropoietin (used for anemia associated with chronic renal failure/AIDS/antiretroviral agents, chemotherapy-associated anemia in amyloid malignancy patient), and tissue plasminogen activator. What was

once just a dream, the ability to regulate and administer drugs in a new and innovative way, has now become a reality. The field of medicine research has undergone thorough investigation by pharmaceutical and other experts over the last 15 years. Drug carriers encompass a variety of substances such as soluble polymers, insoluble or biodegradable microparticles, natural and synthetic polymers, microcapsules, cells, cell ghosts, lipoproteins, liposomes, and micelles. It is possible to construct carriers that are slow to degrade, responsive to stimuli such as changes in pH or temperature, and tailored to specific locations. The process of guiding the drug-loaded system to a certain place is referred to as targeting. While the conventional drug delivery forms include simple oral, topical, inhaled, or injections, more advanced delivery systems need to take into account these factors. In many cases, the effectiveness of therapeutic medicines is contingent upon their ability to exert their influence on target macromolecules that are situated either within or on the surface of specific cell types. The majority of the time, a medicine will only exert its action on a single cell type to achieve the therapeutic effect that is intended. However, many pharmaceuticals interact with enzymes or other macromolecules that are shared by a vast number of cell types. There are particular hormones, for instance, that interact with receptor mechanisms that are only found in a single or a few different types of cells. By allowing the gene to locate its target cell, break through the cell membrane, and reach the nucleus, a perfect gene delivery system would be able to accomplish all of these things. As a result, the therapeutic efficacy of a drug can be improved, and the toxic effects of the drug can be decreased, by increasing the amount of pharmaceuticals that are situated close to the cells that are being targeted, while simultaneously decreasing the amount of drugs that are being exposed to cells that are not the target. The concept of regulated drug distribution is based on this fundamental premise. When designing a controlled drug delivery system, it is necessary to take into account several elements simultaneously. These factors include the characteristics of the medication, the mode of administration, the nature of the delivery vehicle, the mechanism of drug release, the capability of targeting, and the biocompatibility of the system. In Figure 1, a summary of these has been provided. Because these aspects are so highly independent of one another, it is not simple to accomplish all of these in a single system. Furthermore, the most crucial thing to consider when building a medication delivery system is the system's capacity to be reliable and reproducible. The need to achieve precise control and minimize any contribution to intra- and inter-subject variability that may be linked with the drug delivery mechanism is emphasized in this context. There is a wide variety of ways that can be utilized for applications involving controlled medication delivery.

Figure 1: Design requirements for a system that delivers drugs.

An Overview of the Progress Made in the Formulation of Drug Delivery Systems-

These systems offer several advantages compared to other methods of administration:

- The ability to maintain drug levels in the blood within a therapeutically desirable range;
- The potential to reduce or eliminate harmful side effects by delivering the drug locally from a controlled release system;
- The opportunity to improve and simplify drug administration in areas with limited access to medical supervision;
- The ability to effectively administer drugs with a short in vivo half-life;
- The possibility that continuous small doses of the drug may be less painful than larger doses given intermittently;
- The enhancement of patient compliance;
- The use of drug delivery systems may lead to a more cost-effective product and reduced wastage of the drug.

Various applications have been created, encompassing dentistry, immunization, anticoagulation, cancer treatment, narcotic antagonists, and insulin administration. In the context of transdermal distribution, a polymeric system with a contact adhesive is applied to the skin. Research in controlled drug delivery has shown that when a pharmacological agent is enclosed in a polymer or lipid, there is a potential for enhancing drug safety and effectiveness, as well as exploring new therapeutic methods. Multiple rigorous investigations were conducted to develop materials that can degrade, intelligent delivery systems, and techniques for delivering substances through different pathways in the body in response to this concept. Recent endeavors have led to the creation of polymeric drug delivery systems that are capable of responding to stimuli. This has given rise to a novel technique in the realm of controlled drug delivery known as targeted drug delivery.[3]

Several Distinct Methods for The Regulated Distribution of Various Drugs-

Localized Administration of Drugs-

In many instances, it would be desirable to provide medication at a particular location within the body, targeting a particular organ or tissue that is afflicted with a disease. Through the use of this particular mechanism for localized therapy, systemic toxicity might be reduced, and the peak drug level could be achieved immediately at the location of interest. Anti-cancer medications, anti-fertility compounds, and anti-inflammatory steroids are a few examples of the kinds of medications that could benefit from this type of treatment. Not only do these medications have therapeutic effects, but they also have several serious adverse effects that were not intended.

Drug Delivery (Targeted)-

Providing the medicine solely to the cells or components of the cells that are being targeted would be the most effective controlled technique. The development of delivery systems that would match or even surpass the selectivity of naturally occurring effectors (for example, peptide hormones) is required to accomplish this step. The process of drug targeting would most likely involve a recognition event between the drug carrier mechanism and particular receptors located on the surface of the cell, just like it does in the case of hormone action. Cell-type specific immunoglobulins are widely considered to be the most promising choices for targetable drug carriers. A distinction can be made between the concept of targeted drug delivery and that of localized drug delivery. When it comes to sustained drug delivery systems, the controlled release element refers to a system that is dependable and reproducible, and whose rate of drug distribution is not dependent on the environment in which it is located. It is important to note that this requirement emphasizes the necessity of precise control and the elimination of any undesirable contribution related to the drug delivery system.

Modulated drug delivery; the non-zero-order release profile of the Drug--

In the field of drug delivery, one of the most critical challenges is the development of a delivery system that is capable of achieving a non-zero-order release profile that is manipulated. This may be a pulsatile pattern, a

ramp pattern, or another pattern entirely. There are additional circumstances in which the release must take place immediately.

Drug delivery (Controlled feedback)-

A feedback-controlled drug delivery system that releases medicine in response to a therapeutic marker is the ideal drug delivery system. This system is the best drug delivery system. Two categories can be used for this: modulated devices and triggered devices. A modified device can monitor the chemical environment and alter the rate of drug administration continuously in response to a particular external marker. On the other hand, a triggered device does not release any medicine unless it is triggered by a marker.

Drug administration through the nasal passages-

After being administered by the nasal route, medications initially make their way to the respiratory epithelium. It is in this region that compounds can be absorbed into the systemic circulation through a variety of mechanisms, including transcellular and paracellular passive absorption, carrier-mediated transport, and as well as transcytosis. It is possible for the olfactory mucosa to be reached and for drug transport to occur into the brain and/or cerebrospinal fluid (CSF) through the olfactory receptor neurons when a nasal medication formulation is administered deep and high enough into the nasal cavity using the nasal route.[4]

The production of nanosponges involves the utilization of a suitable cross-linking process in conjunction with a wide range of organic and inorganic ingredients. Through the formation of inclusion and non-inclusion complexes, nanosponges can encapsulate a wide range of different types of molecules.[5]

Drug delivery system of liposomal and targeted form-

In principle, drug delivery systems have the potential to improve the efficacy of anticancer drugs while simultaneously reducing their toxicity. Liposomes and other long-circulating macromolecular carriers can take advantage of the 'increased permeability and retention' effect to achieve preferential extravasation originating from tumor arteries. There are variants of liposomal anthracyclines that have considerably longer circulation, such as liposomal daunorubicin and pegylated liposomal doxorubicin. Liposomal anthracyclines have achieved highly effective drug encapsulation, which has led to significant anticancer activity with reduced cardiotoxicity. Pegylated liposomal doxorubicin has demonstrated significant success in the treatment of breast cancer, both when being administered as a monotherapy and when combined with other chemotherapeutic agents. To deliver more medications, further liposome structures are currently being developed. True molecular targeting will be incorporated into the next generation of delivery systems; immune liposomes and other ligand-directed structures are examples of the integration of biological components that are capable of tumor recognition with delivery technology.

Liposomes are structures that are composed of amphipathic phospholipids that are bilayered in a concentric manner. Liposomes can be classed as multilamellar (MLV), small unilamellar (SUVs), or large unilamellar (LUVs) based on the number of bilayers that they include. The size of these objects ranges from 0.025 to 10 µ in diameter. Liposomes can have their size and morphology controlled by the content and the process by which they are prepared. The delivery of medications, vaccines, and genes for a wide range of diseases is accomplished through the utilization of liposomes. Liposomes can be viewed as having evolved from traditional, long-circulating, targeted, and immunological liposomes to stimuli-responsive and actively targeted liposomes based on their composition. This progression can be thought of as a progression. More liposomes are currently in the advanced stages of clinical trials, and a large number of drug delivery systems that are based on liposomes are currently licensed for clinical use to treat a variety of diseases, including cancer, fungal infections, and viral infections.[6]

(TDDS) stands for transdermal drug delivery system-

The transdermal drug delivery method has the potential to offer several benefits, including the avoidance of hepatic first-pass metabolism, the maintenance of steady blood levels for a longer period, the reduction of side

effects, the reduction of gastrointestinal symptoms that are caused by local contact with the gastric mucosa, and the enhancement of compliance. In vitro (ex vivo) models are utilized to investigate the release pattern of TDDS. These models make use of artificial membranes or the skin of animals or cadaveric humans. It would appear that the hairless guinea pig and the Brattleboro rat are suitable models for the investigation of skin and transdermal medication delivery systems in living organisms.

Colon drug Delivery system-

It is widely acknowledged that there are several therapeutic benefits associated with the specific targeting of medications to the colon. Sustained colonic release of medications can be helpful in the treatment of nocturnal asthma, angina, and arthritis. Medications that are destroyed by the acid in the stomach and/or processed by the enzymes in the pancreas are slightly affected in the colon throughout this process. Drugs that are administered directly to the afflicted part of the colon are more effective in treating colonic disorders such as ulcerative colitis, colorectal cancer, and Crohn's disease. In a similar vein, the administration of vermicides and diagnostic chemicals through the colon necessitates significantly lower doses.[7]

Nanocarriers-

Nanocarriers are particles that are smaller than one micron and have a very large specific surface area. As a result, they can provide a greater loading or dosing per unit volume. Because they circulate for far longer periods than the drug alone, they provide increased bioavailability of the drug at the precise location and time where it is required. The medicine is protected from unnecessary degradation thanks to its ability to provide efficient navigation in the complicated environment of the in vivo environment. They can achieve the appropriate therapeutic responsiveness at a far lower dose, which results in a reduction in the risks associated with the medicine. This makes it much simpler to adjust the surface chemistry of nanocarriers to accommodate a variety of medications and compounds that are being targeted. It is possible to achieve both targeted distribution of the medicine as well as sustained and prolonged release of the drug payload.

Through the use of nanocarriers, it is feasible to provide flexibility in forms for a variety of various routes of drug administration and formulations. Not only are they able to be directed to particular cell types, but they may also be directed to particular parts of a cell (for example, the nucleus for gene delivery). It is therefore possible to achieve improved intracellular trafficking of pharmaceuticals by the utilization of nanocarriers. To transport the drug to areas of the body where drug penetration is difficult due to anatomical obstacles, nanocarriers are utilized throughout the process. The blood-brain barrier functions as a selective barrier to the brain, which means that it prevents the majority of the drug from entering the brain. Because nanocarriers can pass through the blood-brain barrier, it is possible to treat the majority of disorders that affect the central nervous system by administering medications in nanocarrier containers. Through either transcellular or paracellular pathways, the nanoparticle achieves its goal of crossing the blood-brain barrier. When it comes to drug delivery systems for specific tissues, the utilization of nanocarriers has become increasingly popular. This is because nanocarriers can reach remote places and tissues, including the ability to pass the blood-brain barrier. It is therefore possible to considerably increase the distribution of pharmaceuticals within the body by administering a drug that is bound with nano-structures or nanocarriers. This will allow for the most effective therapeutic effect possible.[8]

Polymer that is utilized in the control drug delivery system-

When it comes to the subject of medication distribution, polymers are becoming an increasingly significant component. Polymers have a wide range of applications in the pharmaceutical industry, including their usage as binders in tablets, as viscosity and flow regulating agents in liquids, suspensions, and emulsions, and numerous other applications. Polymers have the potential to be utilized as film coatings to conceal the disagreeable taste of a drug, improving the stability of the drug, and modifying the delivery characteristics of the drug.

Polymers as a form of biological material for delivery systems-

Controlling the release of pharmaceuticals and other active agents has been accomplished through the utilization of a wide variety of materials. The first of these polymers was initially designed for other applications that were not related to biology. Some of the materials that are currently being used for controlled drug delivery include:

- Poly(2-hydroxy ethyl methacrylate)
- Poly(N-vinyl pyrrolidone).
- Poly(methyl methacrylate).
- Poly(vinyl alcohol).
- Poly(acrylic acid).
- Polyacrylamide.
- Poly(ethylene-co-vinyl acetate).
- Poly(ethylene glycol).
- Poly(methacrylic acid).[9]

Polymeric nanospheres and nanocapsules are effective drug delivery methods. Compact lipid nanostructures and phospholipids like liposomes and micelles help target medicine delivery. Choosing the best nano-drug delivery technology depends on the biophysical and biochemical features of the medications being used for therapy. Nanoparticles loaded with pharmaceuticals can be designed using green chemistry, which is generally promoted because it reduces the amount of potentially harmful components that are used in the biosynthetic process. The use of green nanoparticles for the delivery of drugs can thereby reduce the adverse effects that are caused by the therapies. Furthermore, modifications to the size, shape, hydrophobicity, and surface variations of nanostructures have the potential to further increase the bioactivity of these nanomaterials. By delivering medicines in a manner that is both site-specific and target-oriented, nanotechnology provides a multitude of advantages for the treatment of chronic diseases that affect humans. Nevertheless, insufficient knowledge regarding the toxicity of nanostructures is a major cause for concern, and it unquestionably calls for additional research to enhance the efficacy while simultaneously increasing the safety of these medications to permit safer practical deployment. In light of this, the careful design of these nanoparticles can prove to be beneficial in addressing the issues that are related to their application. Taking into consideration the aforementioned information, the purpose of this review is to report on various nano-based drug delivery systems, significant applications of nanomedicines based on natural compounds, bioavailability, targeting sites, and controlled release of nano-drugs, as well as other challenges associated with the use of nanomaterials in medicine.[10] The solubility and stability of hydrophobic medications in cancer therapy are improved by polymeric nano-carriers through a variety of mechanisms, mostly related to their distinct structural characteristics and interactions with drug molecules. These carriers, which include micelles and nanoparticles, use their molecular architecture and amphiphilic nature to increase the effectiveness of drug delivery.

Mechanisms of Action

- **Micellar Structure:** Hydrophobic medications can be encapsulated in polymeric micelles, which greatly increases their solubility in aqueous settings. The micelle structure is composed of a hydrophilic shell and a hydrophobic core.
- **Stability in Biological Environments**: In order to ensure continuous medication release in tumor microenvironments, novel triblock copolymers have been created to form stable micelles that resist disassembly in complicated biological fluids.
- **Hydrogen Bonding:** To improve drug loading stability and capacity and to facilitate effective interaction with lipophilic medicines such as doxorubicin, several micelles employ hydrogen-bonding capabilities.

- **Molecular Architecture:** By balancing renal clearance and tumor accumulation, polymeric carrier design can maximize therapeutic efficacy while reducing toxicity. Even though polymeric nano-carriers have a lot of potential to improve medication solubility and stability, there are still issues with assuring their targeted distribution and long-term stability in vivo, which calls for more research in this area.

Polymeric nanocarriers used in Cancer treatment

In contrast to external delivering vehicles, platinum(II) self-delivered nanoparticles free of carriers could serve as alternate options for promotion. Creating cutting-edge, potent platinum (II) anticancer medications that can self-assemble into nanoparticles for self-delivery, as opposed to only offers a simpler synthetic process, but also stays clear of the issues on the exogenous carriers' toxicity and metabolism. For instance, metal cages and platinum(II) metal-cycles are attracting growing interest as a result of their customizable nano architectures and unique antitumor characteristics.[11] Cancer nanotherapeutics is rapidly gaining prominence in global research and is considered a groundbreaking therapy approach in the medical industry. This study outlines the creation of a reliable nanostructured lipid carrier (NLC) method to transport tamoxifen (TAM).In addition, the comparable cytotoxicity of TAM and TAM-NLC against human (MCF-7) and mice (4T1) mammary breast cancer cell lines was identified. When the formulation was kept at a pH that is typical for the body, the rate at which small particles combine to create larger ones decreased, but there was no noticeable change in the ability to absorb light. The study's findings indicate that TAM-NLC shows promise as a medication delivery technology for breast cancer treatment. This article presents the initial positive findings on the impact of TAM-NLC on human and animal mammary cancer cell lines in a laboratory setting. The incorporation of placental growth factor (PlGF) into heparin-based nano-complexes enhances their loading abilities and release capabilities. Similarly, the addition of both PlGF and bone morphogenic protein-2 (BMP-2) further improves these properties. This advancement paves the path for greater bone cell activities while minimizing toxicity. This novel nanocomplex exhibits promising promise in the process of bone regeneration. Lipid nanotubes (LNTs) are highly beneficial materials used for drug delivery and targeting. LNTs composed of specialized compounds known as AQUA (AQ-NH-(CH2)10 COOH) (AQ: anthraquinone group) have been utilized for the transportation of DOX. This lipid nanomaterial is a safe, effective, biodegradable, biocompatible, and stable substance that may be used to carry medications. It has been enhanced for delivering DOX for the treatment of colorectal cancer in the colon. Four different types of pluronic, each with different hydrophilic-lipophilic balance (HLB) values, were altered and attached to a poly-amidoamine dendrimer. The dendrimer nanocarrier was linked with a highly lipophilic pluronic agent, resulting in a greater drug-loading efficiency compared to other modified pluronic. The nanocarriers containing drugs had significant antiproliferative effects on breast cancer cells. Modified cell-penetrating peptides combined with various drug vectors are crucial for drug delivery. These peptides enhance stability during blood circulation and facilitate the development of targeted delivery systems. Nanocages have played a crucial role in advancing and applying various methods for studying biology, green chemistry, material sciences, and nano-drug delivery over the last ten years. Nanocages offer several benefits for drug delivery, including the capacity to reduce premature drug degradation or contact with the biological environment, as well as targeted transportation of cargo to specified tissues. DOX-loaded ferritins are selectively taken up by cancer cells through binding to the overexpressed transferrin receptor. Prominent instances encompass natural nanocages created by structures like ferritins, minuscule heat shock proteins, and vaults, along with diverse viruses such as virus-like particles, cowpea chlorotic mottle virus, cowpea mosaic virus, bacteriophage, and protein-based nanocages employed for drug loadings. A pH-responsive nanocomposite drug delivery system with exceptional drug delivery capacity was created by connecting DOX to xyloglucan (XG) via acid-cleavable hydrazine bonds and then encapsulating DOX through the self-assembly of XG-DOX conjugates. This method improves the transportation of drugs to tumor locations, thus preventing the spread of tumors to other parts of the body. A recent study discovered that

synthesized phospho-ethanolamine efficiently induces apoptosis in several tumor cell types without any negative repercussions. However, its level of safety and ability to selectively target certain areas are particularly remarkable. Quercetin (Que) is a widely recognized chemotherapeutic drug with restricted water solubility. An LMPM delivery vehicle has been used to improve the solubility and bioavailability of Que. An in vivo pharmacokinetic investigation showed that Que-LMPMs displayed a higher area under the concentration-time curve and a prolonged half-life, leading to enhanced bioavailability in comparison to a free Que injection. The PLGA–lovastatin–chitosan–tetracycline NP is a highly effective drug delivery system for tetracycline and lovastatin, particularly in the context of enhancing bone regeneration. The ability of PLGA NPs to regenerate bone was evaluated in beagle dogs with three-walled abnormalities. The obtained data showed that PLGA–lovastatin–chitosan–tetracycline NPs are biocompatible and can act as antibacterial agents to decrease implant infection. In the end, nano-colloids can completely transform the use of NPs. Ultrasound cavitation techniques have been used to construct novel oil-in-water (O/W) nano-emulsions and water-in-oil-in-water (W/O/W) nano-multiple emulsions of aspirin. These emulsions have demonstrated anti-inflammatory and analgesic characteristics. The anti-inflammatory properties of nano-emulsions and nano multiple emulsions were evaluated using the λ-carrageenan-induced paw edema model. The pain-relieving effects of both nanoformulations were evaluated using acetic acid-induced writhing response and hot plate assays. Furthermore, the researchers also examined the anti-inflammatory and antinociceptive characteristics of blank nano-emulsions and reference aspirin suspensions to make a comparison.

Recent Updates-

These days, scientists have created a magnetic medication delivery device that responds sensitively to pH and temperature changes. Unlike previous efforts, this study has employed a clear-cut and accurate technique to create a flexible nanocarrier. The mixture consists of MnFe2O4 magnetic nanoparticles that have been loaded with doxorubicin after functionalization with hydrazide end-groups. Then, a poly (NIPAAm-co-AA) smart polymer with a lower critical solution temperature (LCST) of 38.5 °C was used to envelop these nanoparticles. Research conducted in vitro revealed that pH and temperature had an impact on drug release, with maximal releases taking place at temperatures beyond the lower critical temperature threshold (LCST) of 40 °C and in the pH range of 5–5.3. In addition, the DOX-loaded magnetic smart polymer exhibited a greater cytotoxic effect than the free drug's effectiveness. These results suggest that the magnetic drug delivery system developed in this work has the potential as a novel and promising cancer therapy method.[12] At the same time, the SZBC-NCs (Silibinin-loaded Zein-β cyclodextrin nano-carriers) that were synthesized demonstrated both strong and weak antioxidant activity, which enhanced their toxicity in malignant cells and shielded normal cells from acute oxidative storms, respectively. Additionally, they are a suitable selective colon cancer therapeutic chemical due to their impact on human HT-29 colon cancer cells' cell selective apoptotic response. However, more in-vitro and in-vivo research is required to evaluate the selective anticancer properties of SZBC-NCs.[13] Studying the delivery mechanisms found in nature is an intriguing substitute. A family of extracellular vesicles comprising lipids, proteins, and nucleic acids is known as exosomes. In many biological processes, both pathogenic and non-pathologic, they are the main actors. Tumor-derived exosomes (TDEs) are a further description of exosomes as mediators of tumor-stroma interaction in the development of cancer. It is recognized that this crosstalk has a role in several pathophysiological processes, such as metastasis, treatment resistance, and migration. TDEs can promote migration and cause EMT. This was noted in lung cancer cells, glioblastoma cell lines, and an in vivo model of gastric cancer.[14] Drug delivery refers to either the process or method of giving a pharmaceutical substance to a human or animal to have a therapeutic effect, or to a system that serves as a "carrier" or vehicle for delivering a drug or therapeutic agent to the patient's body. Several kinds of medication delivery systems.

- Drug administration via oral, nasal, ocular, and oral routes.
- Systems for delivering drugs to the lungs.
- Drug administration by sublingual means.

- Drug distribution by transdermal means.
- Medications administered anally or vaginally.[15]

A special kind of synthetic triblock copolymers known as pluronic polymers (pluronic) is made up of hydrophilic polyethylene oxide (PEO) and hydrophobic polypropylene oxide (PPO) organized in the PEO-PPO-PEO order. Pluronics are a perfect and promising biological material that is widely employed in drug administration, illness diagnostics, and therapy, among other applications, because of their outstanding biocompatibility and amphiphilic characteristics. Major advancements in tumor therapy have been made in recent years as a result of the increasing use of pluronic-based multifunctional drug carriers in tumor treatment. A variety of responsive drug carriers are now built with the peculiarities of the tumor microenvironment in mind.[16]

Polymer nanoparticles are innovative carriers for targeted drug delivery in cancer therapy, enhancing tumor selectivity, reducing toxicity, and improving biocompatibility compared to traditional treatment methods.[17] Nano-materials may be created utilizing a variety of nanocarriers, which operate as transport modules for bioactive materials. Pharmaceutical nanocarriers include nanospheres , nanocapsules, nanoparticles, nanoemulsions, nanoliposomes, and nanoniosomes (nonionic surfactant vesicles). These nanoscale drug delivery systems might be natural or manufactured, and they can transport lipophilic or hydrophilic compounds.[17]

Polymeric nanovesicles are used in antitumor drug delivery to reduce adverse effects, improve treatment efficiency, and reduce administration frequency. Recent progress includes synthesizing new amphiphilic isomers for self-assembly into vesicles, regulating membrane permeability to enhance drug transport, and developing hybrid vesicles for multidrug resistance in metastatic tumors. Additionally, nanovesicles combined with immunotherapy show promise in treating malignant tumors by delivering immune stimulators and antigens to antigen-presenting cells. These advancements highlight the potential of polymeric nanovesicles in improving cancer therapy outcomes. The synthesis of a photoresponsive block copolymer prodrug containing a photoreleasable anticancer drug, Chlorambucil (Cbl), and a targeting moiety (biotin) for controlled drug delivery is a novel approach in drug delivery systems. The utilization of polymeric nanoparticles as carriers for drugs, biomolecules, and genes to enhance drug stability, solubility, and targeted delivery is a novel methodology in drug delivery applications. The use of polymeric micelles for cancer immunotherapy, including delivering immunological checkpoint inhibitors, immunostimulatory molecules, engineered T cells, and cancer vaccines, represents an innovative strategy to improve cancer treatment. Comparative examination of N-(2-hydroxypropyl)methacrylamide (HPMA)-based and oligo-(ethylene glycol)methacrylate (OEGMA)-based polymeric drug conjugates for anticancer efficacy, considering their physico-chemical characteristics and biological activity, is a novel approach in cancer therapy research. The application of polymer nanoparticles for targeted drug delivery, gene therapy, and early diagnostics in cancer therapy showcases an innovative method to improve treatment outcomes while reducing side effects.[18] Drug delivery to the central nervous system can be facilitated by combining polymer coatings with nanoparticles (NPs) to cross the blood-brain barrier. [19]

Future Directions and Conclusion-

Progress in molecular pharmacology and a better comprehension of disease mechanisms have necessitated the precise targeting of cells responsible for the onset and advancement of illnesses. This is particularly applicable to the majority of life-threatening illnesses that necessitate treatment medicines with multiple adverse effects. Therefore, precise tissue targeting is necessary to minimize systemic exposure. Modern drug delivery systems (DDS) are developed using cutting-edge technology to expedite the distribution of drugs throughout the body, specifically targeting the desired spot. There is a need to enhance the effectiveness of the treatment while reducing the buildup of drugs in unintended areas of the body. Consequently, they have a significant impact on the management and treatment of diseases. Modern drug delivery systems (DDS) provide significant

advantages over traditional methods. These include improved performance, automation, precision, and efficacy.

Source of funding: None.

Conflict of interest: There are no conflicts of interest.

References-

1. Vaidhya RRB and IS. novel drug delivery systems: an overview. *Int J Pharm Sci Res*. 2013;4(3):970-982.
2. Tobechukwu Christian Ezike a, b, Ugochukwu Solomon Okpala a,*, Ufedo Lovet Onoja a, Chinenye Princess Nwike a, Emmanuel Chimeh Ezeako a, Osinachi Juliet Okpara a, Charles Chinkwere Okoroafor a, Shadrach Chinecherem Eze c, Onyinyechi Loveth Kalu c, Evarist B, Okoroafor CC, Eze SC, Kalu OL, Odoh EC, Nwadike UG, et al. Advances in drug delivery systems, challenges and future directions. *Heliyon*. 2023;9(6):e17488. doi:10.1016/j.heliyon.2023.e17488
3. DONATELLA PAOLINO MASSIMO FRESTA, PIYUSH SINHA MF. Drug delivery systems. In: *Encyclopedia of Medical Devices and Instrumentation*. ; 2006:437-493. doi:10.1007/978-981-13-0152-0_9.
4. Tiwari G, Tiwari R, Bannerjee S, Bhati L, Pandey S, Pandey P, et al. Drug delivery systems: An updated review. *Int J Pharm Investig*. 2012;2(1):2. doi:10.4103/2230-973x.96920
5. Kumar JP, Ismail Y, Reddy KTK, Panigrahy UP, Shanmugasundaram P, Babu MK. Paclitaxel Nanosponges' Formula and in Vitro Evaluation. *J Pharm Negat Results*. 2022;13(7):2733-2740. doi:10.47750/pnr.2022.13.S07.365
6. Sakshi RKS. "Liposomes - An Updated overview." *Int J PHARMA Prof Res*. 2024;15(1):119-127.
7. KSHIRSAGAR NA. Drug delivery systems. *Indian J Pharmacol*. 2000;32(2):S54-S61.
8. Ramakrishna SA* and S. Controlled Drug Delivery Systems : Current Status and Future Directions. *Molecules*. 2021;26:5905. doi:https://doi.org/10.3390/molecules26195905
9. Debjit Bhowmik 1*, Harish Gopinath 1, B. Pragati Kumar 1, S. Duraivel 1 KPSK 2. Controlled release drug delivery systems. *Pharma Innov*. 2012;1(10):24-32. doi:10.1080/10837450.2018.1534376
10. Patra JK, Das G, Fraceto LF, Campos EVR, Rodriguez-Torres MDP, Acosta-Torres LS, et al. Nano based drug delivery systems: Recent developments and future prospects. *J Nanobiotechnology*. 2018;16(71):1-33. doi:10.1186/s12951-018-0392-8
11. Zhang JJ, Xu QJ, Zhang Y, Zhou Q, Lv R, Chen Z, et al. Recent advances in nanocarriers for clinical platinum(II) anticancer drugs. *Coord Chem Rev*. 2024;505(January):215676. doi:10.1016/j.ccr.2024.215676
12. Jafarzadeh F, Peyman H, Roshanfekr H, Azizi S, Idris AO, Maaza M. Fabrication of a Nanomagnetic Smart Polymer Carrier as a Potential Candidate for a Drug Delivery System. *Arab J Sci Eng*. 2024;49(7):9381-9394. doi:10.1007/s13369-024-08724-0
13. Al Alabdullah MAA, Goodarzi MT, Homayouni Tabrizi M. The silibinin-loaded Zein-β cyclodextrin nano-carriers (SZBC-NCs) as a novel selective cancer cell drug delivery system in HT-29 cell line. *Sci Rep*. 2024;14(1):1-9. doi:10.1038/s41598-024-65881-w
14. Ulldemolins A, Seras-Franzoso J, Andrade F, Rafael D, Abasolo I, Gener P, et al. Perspectives of nano-carrier drug delivery systems to overcome cancer drug resistance in the clinics. *Cancer Drug Resist*. 2021;4(1):44-68. doi:10.20517/cdr.2020.59
15. Blair H. Types of Drug Delivery System and Drug Therapies. *J Dev Drugs*. 2022;11(3):1-2. doi:10.35248/2329-6631.22.11.171.Citation

16. Ranjan Kumar Singh, J Pavan Kumar, Chennu MM Prasada Rao, Rajeswari Tannairu, and Ajay Garg. "recent developments in quercetin-loaded nanoparticles for cancer targeting". *Tropical Journal of Pharmaceutical and Life Sciences*, vol. 12, no. 1, Feb. 2025, pp. 11-23, doi:10.61280/tjpls.v12i1.174.
17. Yu J, Qiu H, Yin S, Wang H, Li Y. Polymeric drug delivery system based on pluronics for cancer treatment. *Molecules*. 2021;26(12):1-23. doi:10.3390/molecules26123610
18. Kumar JP, Rao CMMP, Singh RK, Garg A. A brief review on encapsulation of natural poly-phenolic compounds. *Adv Pharm J*. 2024;9(April):33-39. doi:10.31024/apj.2024.9.2.1
19. Pavan Kumar J, Prasada Rao CM, Singh RK, Garg A, Rajeswari T. A Comprehensive Guide to Hydrogel-Based Controlled Drug Delivery for Cancer Treatment. *J Drug Deliv Ther*. 2024;14(8):195-200. doi:10.22270/jddt.v14i8.6732
20. J Pavan Kumar, Chennnu MM Prasada Rao, Ranjan Kumar Singh, Ajay Garg, Tanniru Rajeswari. A comprehensive review on blood brain delivery methods using nanotechnology. *Trop J Pharm Life Sci*. 2024;11(3):43-59. doi:10.61280/tjpls.v11i3.162.

How to cite this article: J Pavan Kumar, Ranjan Kumar Singh, Chennu MM Prasada Rao, Rajeswari Tannairu, & Ajay Garg. (2025). POLYMERIC NANO-CARRIERS FOR DRUG DELIVERY SYSTEMS IN CANCER THERAPY - AN EXHAUSTIVE REVIEW. *Tropical Journal of Pharmaceutical and Life Sciences*, *12*(1), 33–44. https://doi.org/10.61280/tjpls.v12i1.176

Published by:
Informative Journals
Jadoun Science Publishing Group India