ECO-FRIENDLY DRUG DELIVERY SYSTEM

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ABSTRACT

Drug delivery systems (DDS) are essential for the efficient and secure administration of medicinal drugs. The development of environmentally friendly DDS is a recent trend aimed at minimizing the environmental impact of conventional systems, which frequently include synthetic materials that are not biodegradable. Eco-friendly DDS use biodegradable and renewable components from plants and marine organisms to maximize therapeutic effect with the least amount of environmental harm. Biodegradable and naturally occurring polymers including cellulose, chitin, chitosan, and collagen are important components. DDS is further optimized by technologies such as nanotechnology, which enhance its bioavailability, facilitate targeted distribution, and lessen its negative effects. The utilization of marine and plant-based systems in the development of sustainable DDS is highlighted via case studies. Eco-friendly DDS have advantages, but there are problems with material extraction, purification, and standardization. Personalized medicine, improved nanotechnology, and multidisciplinary research are some of the future directions. All things considered, environmentally friendly DDS offer an alternative for traditional techniques, supporting sustainable advancement in medicine.

Keywords—Eco-friendly, Drug Delivery, Biodegradable

I. INTRODUCTION

Drug delivery is defined as the formulation or device that enables the introduction of therapeutic substance into body and improves its efficacy and safety by controlling rate, time and place of release of drug in the body. Drug delivery system is an interface between the patient and drug, it should undergo several preclinical and clinical trials to understand the pharmacokinetic and pharmacodynamic nature. Currently Drug Delivery with environmental sustainability is raising awareness to develop eco-friendly drug delivery system, as convectional drug delivery system often uses synthetic materials or polymers and that can cause harmful impact in environment by processing those synthetic polymers, can lead to non-biodegradability, increase in toxicity, to address these issues industries, scientific and medicinal field emerging to development of Eco-friendly drug delivery system by using the renewable materials which are derived from natural sources like plants, marine organism and biodegradable polymer thus minimizing the environmental impact, thereby enhancing therapeutic index and patients & environmental safety. The advantages of Eco-friendly drug delivery is beyond the expectations by providing increases bioavailability, improved biocompatibility, reducing the adverse effects, improving the patients compliance etc., by using the natural and

biodegradable polymers also has several advantages like increased drug stability, targeted site drug release and help in achieving sustained and controlled drug release. However, materials processed for eco-friendly delivery is not without challenges, for material's extraction and purification should provide advanced and standardization techniques for ensuring quality and these procedures should go through the assessed regulatory needs. Ecofriendly drug delivery plays a pivotal role in medicinal field by taking significant step in pharmaceutical industry, by use of natural biodegradable polymers it gives alternative to the conventional drug delivery and aligning towards the green and sustainable environment (1).

II. MATERIAL USED FOR ECO-FRIENDLY DDS

A. BIODEGRADABLE POLYMER

Biodegradable polymers break down both enzymatically and non-enzymatically, yielding safe and biocompatible byproducts in the process. A significant focus of biodegradable polymers is the chemistry of novel compounds in targeted medication delivery applications. Biodegradable biomaterials are well permeabilized, have no persistent inflammatory effects, and have good medicinal qualities. Presently, polypropylene, polyethylene, and polyvinyl chloride are the most common biodegradable thermoplastic polymers used as matrix for natural fibres instead, thermoset materials like polyester and phenolics are also frequently used. It is possible to distinguish between two types of biodegradable polymers: synthetic and natural. Certain polymers are made from feedstocks that come from biological (renewable resource) or petroleum (non-renewable resource) resources. Natural polymers typically have fewer benefits than manufactured ones. As "green" alternatives to synthetic polymers, biodegradable polymers are still not widely used. Additionally, using biodegradable plastics seems like a good way to improve environmentally friendly and sustainable farming practices, particularly when it comes to mulching and growing. The preservation of forests and forest resources has also contributed to the growing interest around the world in agro -based structural materials derived from naturally occurring, yearly renewable, and biodegradable sources. Examples of biodegradable polymers are: polyphosphates, polyadipic acid, poly(Lactic acid), poly(Glycolic acid), poly(Imino carbonates), polyorthoesters, etc.(2)

B. NATURAL POLYMER

In recent years, biodegradable polymers made from renewable resources have garnered a lot of interest. All organisms undergo growth cycles that result in the formation of natural polymers. Biopolymers are naturally occurring, biodegradable polymers. Among these naturally occurring polymers, the polysaccharide family includes starch and cellulose. Biodegradable materials can be made with proteins or other natural polymers. These are the two primary renewable biopolymer sources. Lipids are an additional resource. They also have high reactivity, are non-toxic, biocompatible, and biodegradable. Natural polymers are frequently chosen over synthetic ones due to their effective use of renewable biomass and lower environmental impact. Examples of natural polymers are: cellulose, chitin, chitosan, agarose, dextral, gelatin, albumin, collagen, etc.

- CELLULOSE

Since cellulose is the most common renewable resource, it may be obtained for a reasonable price. Due to its various benefits, cellulose has become one of the most widely utilized natural polymers, especially in light of the growing demand for more biocompatible and environmentally friendly materials.

- CHITIN

One of the most prevalent polysaccharides is chitin, also known as poly (N-acetyl-D-glucosamine). It is frequently present in the internal flexible shells of cephalopods, the exterior skeleton of arthropods, and the fibrous components that make up the cellular walls of algae and mushrooms. Chitin is valued for its beneficial qualities, which include low antigenicity, excellent crystallinity, low toxicity, biodegradability, and biocompatibility (both in nature and in the bodies of animals).

- CHITOSAN

Chitosan, a valuable compound with biological properties such as anti-cancer, immune-enhancing effects, and antioxidant properties, can be produced by extracting chitin from the shells of crustaceans. This process has the potential to reduce waste and find applications in various fields, including food, medicine, pharmaceuticals, and cosmetics. Based on the findings of several investigations, chitosan, a naturally occurring, non-toxic, biodegradable polysaccharide generated from chitin, has the potential to be employed as a natural antibacterial or antimicrobial.

- COLLAGEN

Typically, collagen is extracted from natural sources, such as a variety of animal tissues, or it can be produced artificially using fibrils that mirror the properties of collagen or by recombinant protein synthesis systems using yeast, bacteria, mammalian cells, insects, or plants. Since collagen fibre is the primary component of leather, it is possible to economically get collagen from solid waste leather. Excellent biocompatibility and biodegradability are displayed by this type of collagen.

- GELATIN

Collagen is hydrolyzed multiple times to produce gelatin, a biomass resource that is both nontoxic and biodegradable. Gelatin finds application in numerous disciplines, including biomedical, antimicrobial, packaging, adhesives, food packaging, tissue engineering, and adsorbent (3).

III. TECHNOLOGIES IMPLEMENTED IN ECO-FRIENDLY DDS

A. Nanotechnology:

Nanotechnology, defined as the study of functional system at micro level or material on a atomic scale, this emerged as a huge transformation in various domain including medicine. It has been a promising technology in drug delivery system and nanotechnology based drug delivery produced innovative solution to the limitation faced in conventional drug delivery system such as poor solubility, disintegration which leads to the problem in drug distribution, bioavailability and increase in side-effects. Nanoparticles ranges from 5-200nm in size, these particles are incorporated with various carriers like polymers and lipids are used in drug delivery system in which they can achieve drug delivery to the specific cell or receptor and gives functioning according to that moreover they help us to minimize the dosage and also enhances the therapeutic index. However, nanotechnology drug delivery advancements in achieving personalized medicine by taking into account of individual patient profile and customizing medicine according to their treatment response and thus reduces adverse effects (4).

B. Sustained and controlled release:

Methods of achieving the controlled release (5),

Table 1: Different types of Nanocarrier and their Application

Nanocarrier	Application
Liposomes	Biodegradable, safe to use, mostly implemented for systemic drug release.
Nanocrystals	Helps in smaller dosage form thus side effects are decreased
Solid lipid nanoparticles	Non- toxic and protect from degradation

IV. CASE STUDIES IN ECO-FRIENDLY DDS

A. Plant based system

Drug delivery system have advanced significantly in producing the eco-friendly delivery in healthcare particularly those derived from natural sources. Their aim is to produce not only effective treatment but also to develop environmentally sustainable practices. Phytochemicals extracted from plants are higher in biocompatibility, biodegradable and minimal toxicity and also paved way to new ideology for novel drug delivery. Plant based system plays a crucial role in healthcare and gives alternative to convectional drug delivery system while minimizing the environmental impact. Some of the examples of plant-based system are: (6)

- Arglabin was extracted from *Artemisia glabella*, a essential oil which is derived from the plant parts of leaves and flowers used to treat several diseases but its gives promising treatment various types of tumors (7).
- Resveratrol is a biochemical compound found in plant *Polygonum cuspidatum*, its roots have been used to treat skin related problem as well as intestinal inflammation (8).
- Curcumin is most common compound derived from the species *curcuma longa,* which is usually used as antioxidant, anti-inflammatory and anti-cancer (9).

B. .Marine based system:

Marine derived are rich in lipids, proteins, polysaccharide, amino acids, alkaloids etc can be utilized in drug delivery. Marine based drug delivery system(MDDS) uses marine organism such as sponges, sargassum, algae, seaweeds etc, has a major ecological impact in delivering eco-friendly system. The major advantage of marine product is resources are renewable, reduces the utilization of synthetic resources and can be used to create biodegradable, biocompatible and eco-friendly products. However extraction and purification of these materials has been a bit challenging but they are upgraded to ensure the product safety and quality. In conclusion, MDDS shows a promising eco-friendly delivery and gives alternative to traditional drug delivery and the marine resources should be maintained carefully and preserve biodiversity. Some of the examples of marine based drug delivery: (10)

- Exoskeletons of crustaceans, crabs, shrimps produces chitin and chitosan has a various properties like biocompatibility, mucoadhesive and wide application of drug delivery in wound healing, vaccine adjuvants etc.
- Alginates, a polymer derived from brown seaweed helps the drug to controlled release and changes according to pH or ion concentration and also forms hydrogel that can be encapsulated in drug (11).
- Carrageenans a sulphated polysaccharides extracted from red seaweed forms carrageenan gel used for controlled drug release (12).

V. BENEFITS AND CHALLENGES

- **ENVIRONMENTAL SUSTAINABILITY**: In light of this, the area of bionanomaterials has moved its focus to the creation of environmentally friendly synthesis techniques and the utilization of sustainable materials. Along with other important concerns and difficulties in biomedical science, such as the extremely effective targeted delivery of materials and chemicals that have limited toxicity and side effects, all of them must be taken into account for clinical applications.
- **BIOCOMPATIBILITY:** The biocompatibility and sustainability of biopolymers make them a potential better option than synthetic polymers. The manufacturing of biocompatible drug delivery vehicles using chitosan-based nanocomposites, with an emphasis on anticancer, gene delivery, microbial treatment, and wound healing.
- **REDUCED TOXICITY**: Synthetic polymers, known generically as plastics, are produced from basic raw materials called monomers, which are subjected to specific chemical reactions (polymerization, polycondensation, and polyaddition) under particular conditions. These non-renewable polymers produce some major problems like water, air, and soil contamination that directly affect the environment and health. So, biopolymers have been developed that present physicochemical and thermoplastic properties similar to petroleum-based polymers, with the difference of being biodegradable. These renewable polymers have potential environmental impacts because of their low toxicity.

- **ENHANCED DRUG STABILITY AND EFFICACY**: The optimum drug loading and releasing properties of polymeric drug delivery devices have made them highly desirable for controlled delivery. But synthetic polymers have considerably more negative consequences than positive ones, which might cause problems such as dose decreases, treatment delays, or interrupted therapy. Research has chosen natural polymeric materials, including biopolymers and their composites, as excipients due to their low toxicity, stability, biodegradability, and cyclical nature. Additionally, because of their unique qualities, they possess a wide range of architectures, specific physiological roles, and may offer a number of biological applications.
- **VERSALITY AND FUNCTIONALITY:** Pullulan (obtained from Aureobasidium pullulans) has become more and more relevant in the food, pharmaceutical, and cosmetics industries because of its versatility. Pullulan is a highly soluble substance in water that is also odourless, tasteless, edible, and biodegradable. Benefits include not being carcinogenic, toxic, immune- or mutagenic, and—most importantly—being regarded as "generally regarded as safe" (GRAS), which makes it a solid option for use in industries. Pullulan is hydrophilic in nature; it makes complexes with a variety of drugs, especially hydrophobic drugs. By adjusting the hydrophilic-hydrophobic ratio in the structure of the support macromolecule and promoting different kinds of physical interactions between the drug and carrier, this type of drug transport targets cells like cancer cells or liver cell receptors and is also used for some treatments like lung disease and cancer treatment (13).

Challenges (14)**,**

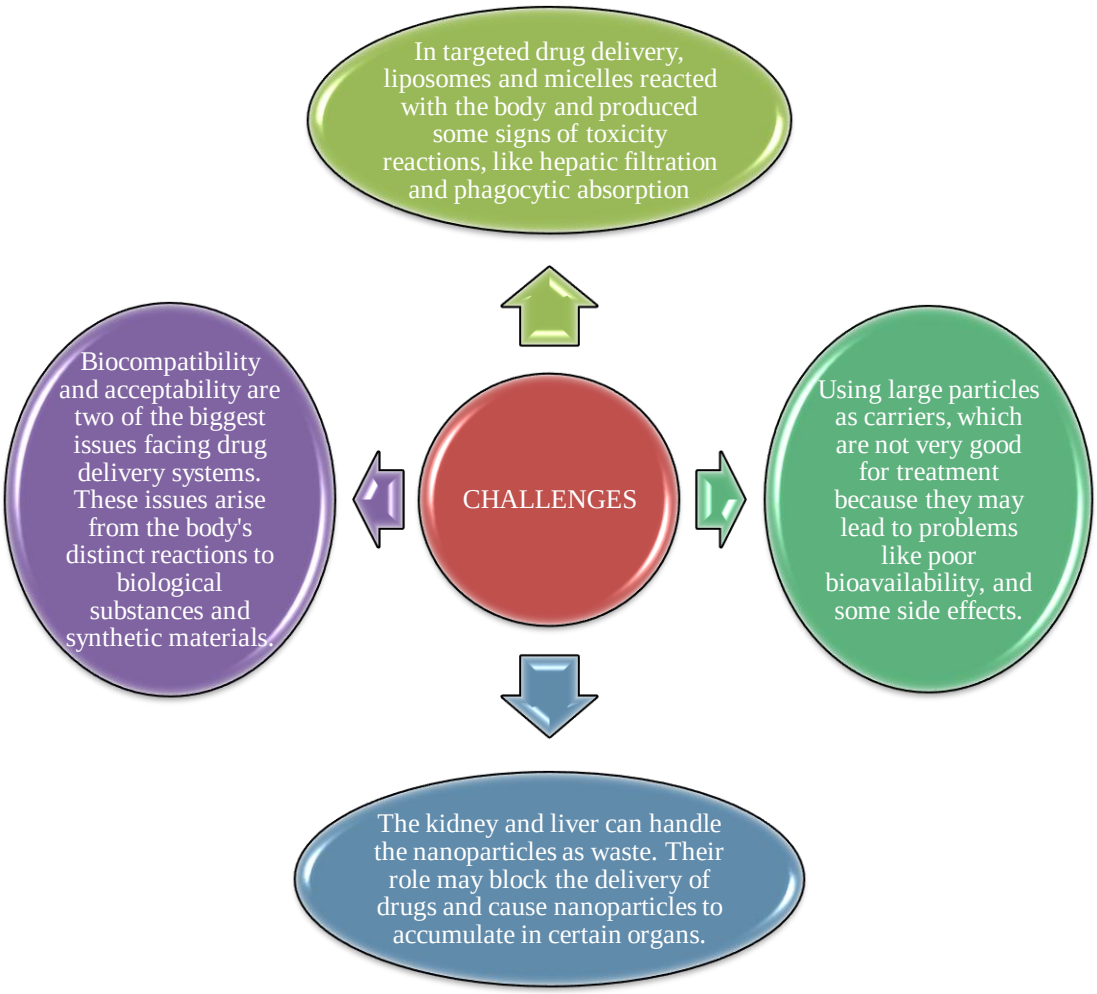

Figure 1: Challenges in Eco-friendly DDS

VI. FUTURISTIC TRENDS IN ECO-FRIENDLY DDS(15)

As research progresses, new technologies emergers. There are some of the future direction to develop eco-friendly drug delivery system :

- Personalized medicine:

Developing dosage form according to the patients- specification by considering there lifestyle, disease and environmental factors etc. and also helps to delivery the drug to patients in specific site which gives them effective treatment and less side effects.

- Nanotechnology implementation:

In future, nanoparticles plays a vital role in various fields like screening, therapy drug targeting and also helps in real time monitoring of therapeutic outcome and also it can paw way to green synthesis method where nanoparticles are incorporated with plant extracts and compounds are developed thus it reduces the use of synthetic material by minimizing the environmental impact.

- Interdisciplinary research and collaboration:

In future, eco-friendly drug delivery collaborates with various fields like medicinal, engineering, biotechnology etc and can develop relationship between firms and government and can incorporate this methods and techniques in academics which leads to innovative research and projects.

VII. Conclusion:

Eco-friendly delivery shows a significant scope in future in pharmaceutical fields as it serves as alternative to convectional drug delivery, by implementing new techniques like nanotechnology, use of biopolymers , natural polymers and green synthesis methods in order to decrease the use of synthetic material in developing drug thus it minimizes environmental impact. There are various case studies like plant based and marine based which involves in developing eco-friendly drug delivery system. Various significance like biocompatibility, reduced toxicity, sustainability and environmental impact, personalized medicine and reduces adverse effects thus increasing therapeutic profile can be achieved by eco-friendly delivery. However these cannot be achieved without challenges. In future these techniques should be collaborated with various interdisciplinary fields for the innovative solution to the modern problem. Thus ongoing advancement in this field to contribute the sustainable healthcare.

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