CODEN [USA]: IAJPBB ISSN: 2349-7750

INDO AMERICAN JOURNAL OF
PHARMACEUTICAL SCIENCES
http://doi.org/10.5281/zenodo.3275427

Available online at: http://www.iajps.com *Review Article*

A REVIEW ON MAGNETIC DRUG DELIVERY SYSTEMS: A NOVEL APPROACH FOR DRUG TARGETING

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Article Received: May 2019 **Accepted:** June 2019 **Published:** July 2019

Abstract:

Recent advances in novel drug delivery (NDDS) aims to enhance the safety and efficacy of drug molecule by formulating a convenient dosage form for ease of administration and to achieve better patient compliance. A number of approaches are available in delivering therapeutic substance to the target site in sustained and controlled release fashion. One such approach is using magnetic drug delivery as carriers for drugs. Magnetic drug delivery systems has gained vast attention due to its diverse applications that range from prominent technique for site-specific targeting of various pharmacological agents and helping the diagnostic features. Magnetic carriers like nanoparticles, microspheres, liposomes and emulsion have been found advantageous of the fact that they reduces the free drug concentration in the blood and to minimize the adverse effects provoked by these drugs. It has made the most crucial tumor targeting possible without damaging the healthy tissues. In this review, we will summarize the facts about magnetic drug delivery systems comprehensively. This article focuses on the type, advantages, disadvantages and factors affecting magnetic drug delivery systems, this review also provides the detailed concept of some unique technologies.

Key words: *Magnetic drug delivery systems, Magnetoliposomes, microcarriers, supramolecular.*

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*Please cite this article in press Vishal Hire et al., A **Review On Magnetic Drug Delivery Systems: A Novel Approach For Drug Targetin**., Indo Am. J. P. Sci, 2019; 06(07).*

INTRODUCTION:

The purpose of this thesis is to consider how externally applied magnetic fields can be used to guide materials internal to the body. The primary concern will be to examine current and prior attempts to discover a fusion of past designs that allow the guidance of magnetic microspheres. It is hypothesized that control of magnetic microspheres *in vivo* is feasible given a strong magnetic field and gradient space superposition on an arterial system.

This work is fueled by the general nanotechnology initiative and the general desire for less invasive surgery using electromagnetic field-directed nanoparticles. The current nanotechnology initiatives are motivated by the added functionality derived from reducing the overall size of working systems. A general overview of the most important variables of concern and background is presented in the first section. Next, a review of prior and present magnetic field-based delivery systems will be explored. Modeling the controlling variables and their interactions are described in closer detail in the third section. Finally, in the fourth section, first-order experimental verification is performed to ensure the accuracy of the modeling. The end discussion summarizes results and provides recommendations for future research. [1]

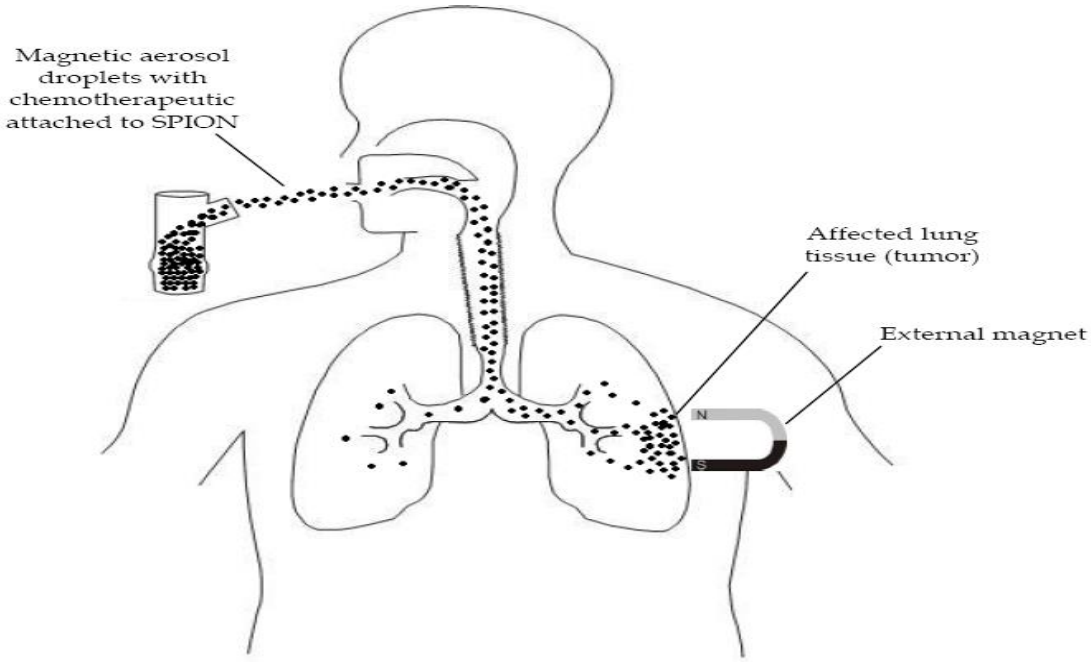

Figure 1: The concept of non-invasive delivery of magnetic aerosol droplets to the human lungs and concentrated to the target site (tumor) with the help of magnet.

Selective targeting of therapeutics is one of the greatest challenges in designing site-specific drug delivery system in which drugs are required to accrue at the exact location for its pharmacological action. Increased drug concentration remains a critical concern as drugs are unable to accumulate at the specific receptor, organ or any other part of the body resulting in toxicity to the healthy tissues. To overcome such problems in site-specific targeting, different chemical properties are modified including partition coefficient, attachment of ligands, altered charge density and creation of various biodegradable polymers.

Mononuclear phagocytes of Reticulo-endothelial system (RES) also creates an apparent obstacle by sequestration of these careers. Magnetic responsive drug delivery systems are designed for the site specific targeting of drugs without disturbing RES in which external magnetic field is applied to increase the drug concentration at tumor site after administration of magnetic particles. These careers are restricted to RES by biophysical means to localize them specifically at the desired site of action. Such system is also titled as “drug delivery polymeric magnetic particles” because different biocompatible and biodegradable polymers are used to envelope

magnetic particles along with the drug. Non-magnetic micro careers are also used for targeting of drug but due to their clearance by RES, they show poor site-specific action.

There are a number carriers Microspheres, nanoparticles, liposomes and others for which optimized technologies are under development to,

a) enhance the performance of products that have already been delivered with some success via that route and

b) modulates the release and absorption characteristics of the drugs particularly those drugs which have shorter biological half life.

Dosage forms that can precisely control the release rates and target drugs to a specific body site have created enormous impact on the formulation and development of novel drug delivery systems. The objective of controlled release drug delivery includes two important aspects namely spatial placement and temporal delivery of drug. Spatial placement relates to targeting a drug to a specific organ or tissue, while temporal delivery refers to controlling the rate of drug delivery to the target tissue. [2]

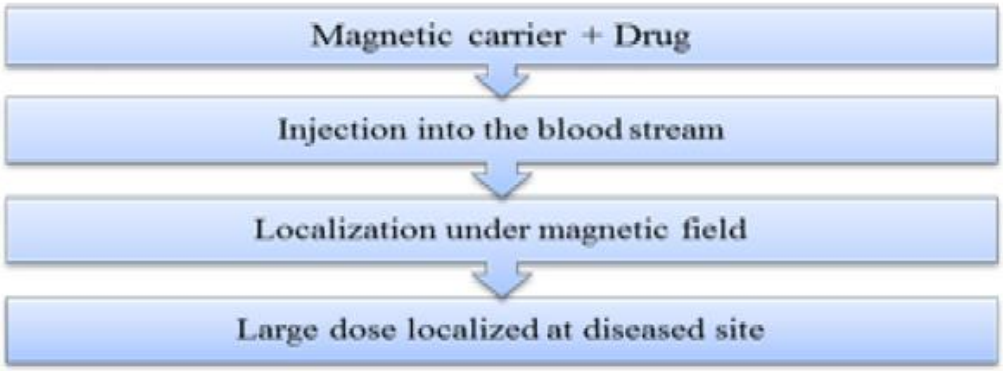

Figure 2: Mechanism of action for magnetic targeted drug delivery systems.

❖ **Concept of Magnetic Drug Targeting [3]:-**

Magnetic targeting is one of the productive methods to deliver the drug at diseased site by virtue of a magnetic compound. These drug delivery systems contain magnetic responsiveness being integrated from different substances like magnetite, iron, cobalt, nickel, iron-boron or samarium-cobalt. The drug along with the magnetic compound is injected into the patient's blood circulation system and a magnetic field is applied at the target site to block it. Thus, considerable less amount of drug concentration can be achieved at specific site which minimizes the unwanted effects due to the high drug concentrations of freely circulating drug as shown in Figure 3.

MECHANISM OF ACTION [12]

The aim of the specific targeting is to enhance the efficiency of drug delivery & at the same time to reduce the toxicity & side effects. Magnetic drug transport technique is based on the fact that the drug can be either encapsulated into a magnetic microsphere (or nanosphere) or conjugated on the surface of the micro/nanosphere. Efficiency of accumulation of magnetic carrier on physiological carrier depends on physiological parameters like particle size, surface characteristic, field strength, & blood flow rate etc. The magnetic field assists to extravasate the magnetic carrier into the targeted area. Some kinds of channel opened by the force of the magnet are thought to be associated with process of extrusion by magnetic targeted carriers. This technique, which requires only a simple injection, is far less invasive than surgical methods of targeted drug delivery.

Another advantage is that particles in the magnetic fluid interact strongly with each other, which facilitates the delivery of high concentrations of drug to targeted areas. Magnetic system for concentrating magnetic particles in an organ/tumour can be seen in fig.

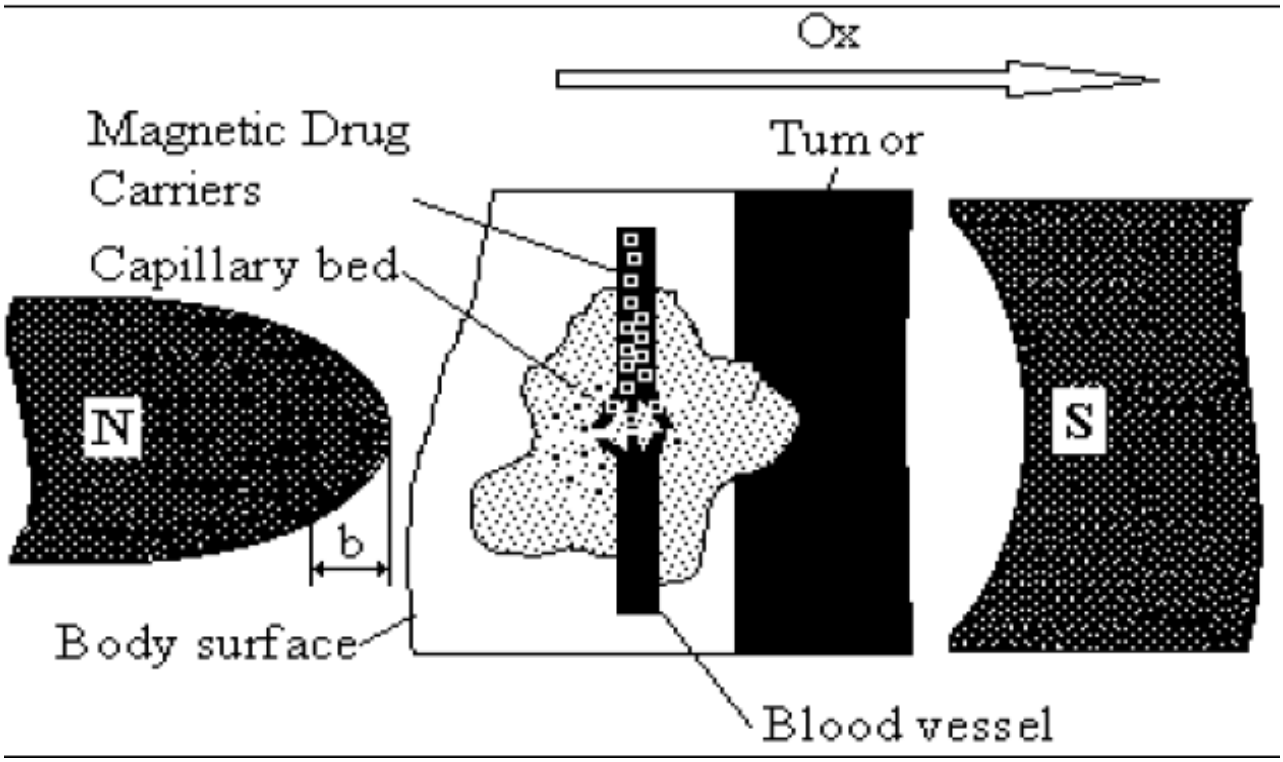

Figure 3: Magnetic system for concentrating magnetic particles in an organ/tumor.

Magnetic materials were suggested as carriers for protein immobilization. Their property to concentrate near magnetic terminals is used in technological process for selective catalyst removal from the reaction mixture, in immunological studies for separation of cells to which magnetic particles are specifically bound modified targeting in vivo into appropriate tissues under guidance if an external magnetic field. A number of methods are available to obtain porous magnetic carriers, containing immobilized matter not only on the surface, but also in the volume of a particle. Normally, these preparations are obtained by granule formation from the suspension of ferromagnetic particles in the solutions or melt of appropriate high molecular weight compound. The drawbacks of the above mentioned methods include pronounced aggregation of ferromagnetic particles and lead to formation of product with a variety of sizes and magnetic properties.

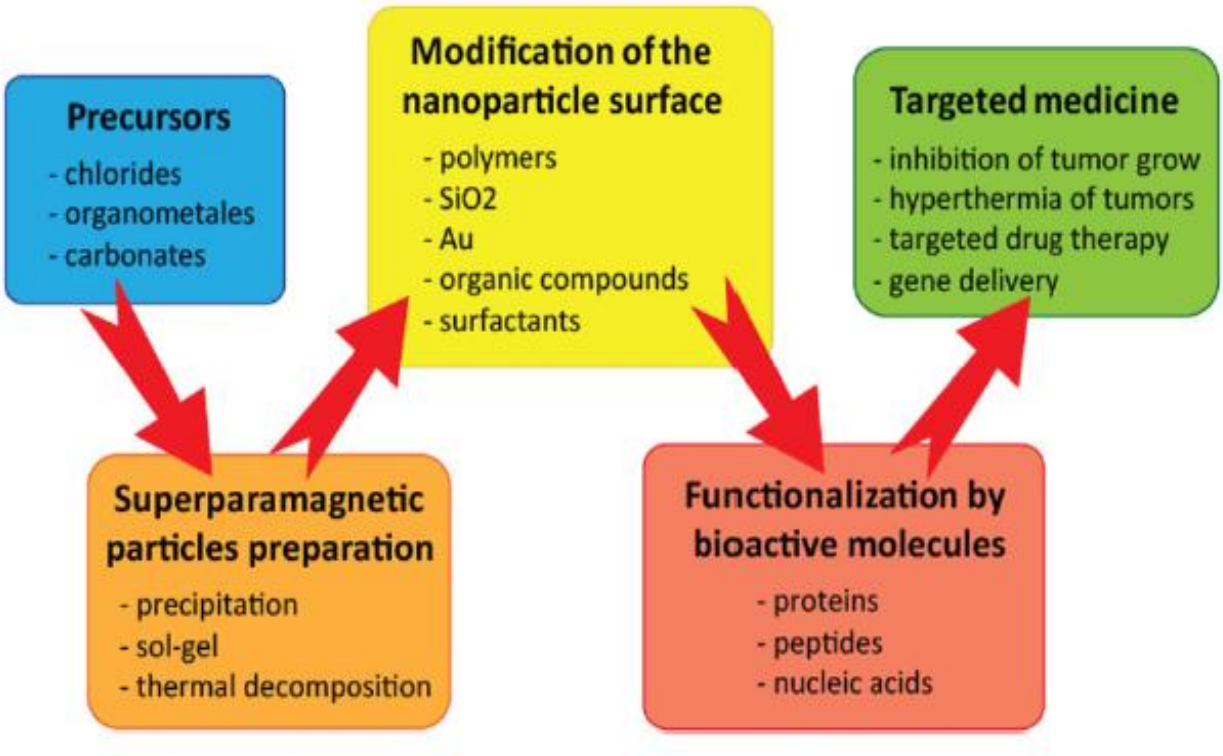

Figure 4: Processes of magnetic particles preparation for drug delivery.

TYPES:

❖ **Magnetic carriers:-**

Magnetic microcarriers are supramolecular particles that are small enough to circulate through capillaries without producing embolic occlusion, but are sufficiently susceptible (ferromagnetic) to become captured in microvessels and dragged in to the adjacent tissues by magnetic fields of 0.5-0.8 tesla (T). These microcarriers include microsperes, liposomes, cells, nanoparticles etc.

➢ **A. Magnetoliposomes:-** [13]

These are magnetic carrier which can be prepared by entrapment of ferrofluid within core of liposomes. Magnetoliposomes can also be produced by covalent attachment of ligand to the surface of the vehicles or by incorporation of target lipids in the matrix of structural phospholipids. Alternatively magneto liposomes are prepared using the phospholipid vesicle as a nanoreactor for the in situ precipitation of magnetic Nano particles. Vesicles are also prepared containing didodecyl methyl ammonium bromide; contain an ionic magnetic fluid.

➢ **B. Magnetic Nanoparticles:-** [14]

Magnetic colloidal iron oxide nanoparticles were prepared with the method of co precipitation. Interfacialpolymerization was also applied to synthesize magnetic nanoparticles. Bacterial magnetite nanoparticlesobtained from magnetotactic bacteria after disruption of the cell wall & subsequent magnetic separationhave been used for a variety of bioapplications. Due to the presence of the lipid layer these particles arebiocompatible, their suspensions are very stable & the particles can be easily modified.

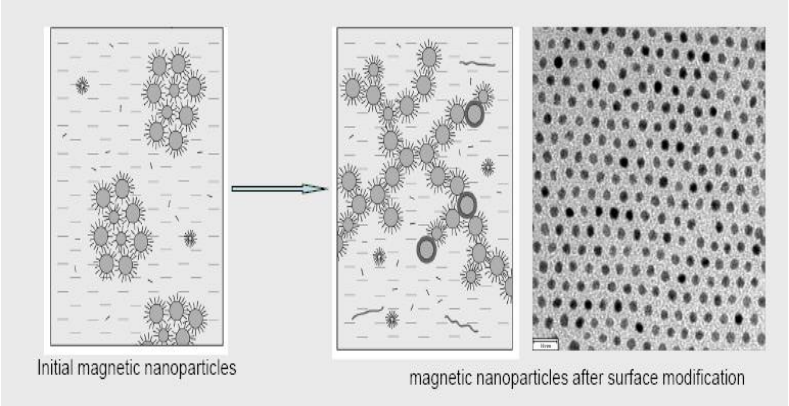

Figure 5: Surface Modification of Magnetic Nanoparticles.

➢ **C. Magnetic Resealed Erythrocytes:-** [14]
Magnetically responsive drug-loaded erythrocytes were prepared and characterized in vitro. The erythrocytes loaded with drug and magnetite (ferrofluids) using the preswell technique. The loaded cell effectively responded to an external magnetic. In the continuous study, drug bearing erythrocytes were prepared by preswell technique and characterized for various in vitro parameters.

➢ **D. Magnetic Emulsion:-** [15]
Magnetic emulsion was also tried as drug carrier for chemotherapeutic agents. The emulsion is magnetically responsive oil in water type of emulsion bearing a chemotherapeutic agent, which could be selectively localized by applying an external magnetic field to specific target site.

➢ **E. Magnetic Microspheres:-** [16]
The use of magnetic force for the site-specific drug delivery by using albumin microspheres containing magnetite appears to be a promising strategy. Significant improvement in response can be incorporated and obtained with the magnetic albumin microspheres drug regimens. In the presence of suitable magnetic field, the microspheres are internalized by the endothelial cells of the target tissue in healthy as well as tumor.

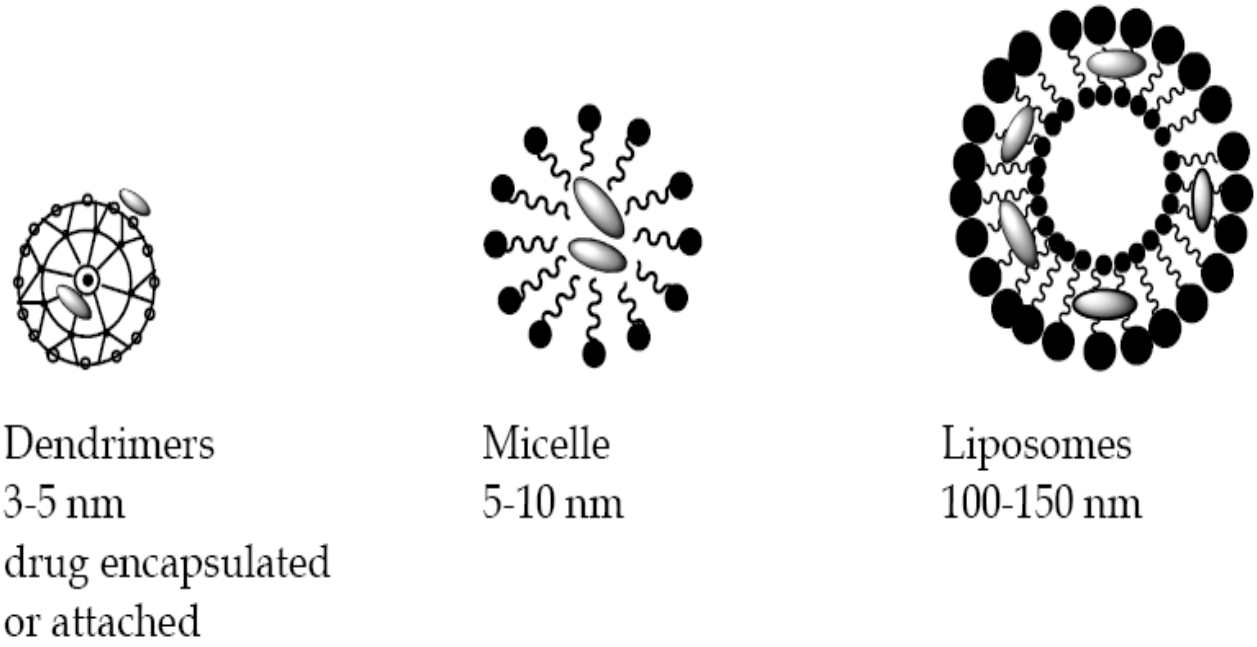

Figure 6: Types of Microspheres.

CLASSIFICATION OF MAGNETIC DRUG DELIVERY SYSTEM

To achieve controlled and targeted delivery of drug, magnetic carrier drug delivery systems (DDS) can be categorized further into;

6.1 Magnetic Nanoparticles
6.2 Magnetic Microspheres
6.3 Magnetic Liposomes
6.4 Magnetic Emulsions

❖ **6.1 Magnetic Nanoparticles:-** [17]

Recent decades have shown a vast range of applications in the field of magnetic nanotechnology as it has expanded its scope to oncological, cardiovascular and neurological disorders. They have been under keen investigation in different fields as next generation drug carriers due to their physical properties. Magnetic nanoparticles have displayed a great potential in drug loading proficiency due to their magnetic core intrinsic capabilities and physico-chemical properties due to the coating efficiency.

These particles having size less than 100 nm, are employed under the influence of magnetic field and manipulated by different materials such as iron, nickel, cobalt. Enhanced performance is deliveredbelow a critical value of their size which is around 10-20 nm. These nanoparticles show super magnetic behavior above blocking temperature and acts like paramagnetic atoms showing less resonance.

They can be used in different ways like magnetic resonance imaging, vascular contrastingagents, diagnosing agents as theranostic in targeting of cancer treatment , targeting of genes, tissue engineering, bio separations, cell tracking.

However, problems of intrinsic instability can occur over longer period of time as they can easily oxidize in air causing loss of the magnetic property.

➢ **6.1.1 Advantages of Magnetic Nanoparticles:-**

- ❖ Excess amount of drug is reduced minimizing unwanted effects.
- ❖ Frequency of administration is reduced.
- ❖ Reduced side effects of drugs as compared to conventional dosage form.
- ❖ Targeted organ receive prolonged delivery of drug.
- ❖ Diseased organ receive sustained drug delivery.

❖ **6.2 Magnetic Microspheres:-** [18]

Magnetic microparticles comprise of different materials, having strong magnetic moment which can successfully deliver non-magnetic substances like cells, antibodies, drugs, nucleic acids and enzymes to the magnetic field. These are smaller in size i.e. less than 4 μm, which provides an efficient flow rate to pass through capillaries without formation of embolus.

They consist of biocompatible proteins or synthetic polymer to which the drug is bound and are formulated to be used in depot form near targeting site by nearby placing suitable magnet. To avoid unwanted distribution of drug to non target organ help in drug localization and avoid toxicity. It was propounded by Gupta and Hung that magnetic microspheres can cause 16 fold increase in drug concentration, 6 fold increase in drug exposure and 6 fold increase in targeting efficiency of the system.

❖ **6.3 Magnetic Liposomes:-** [19]

Magnetic liposomes consist of bilayered compositional structure in which lipid layer and aqueous layer are designed in alternative patterns. These are biocompatible vesicular shaped structure having nanometric size, being used to encapsulate water soluble and oil soluble therapeutic agents. Water soluble active ingredients are incorporated in aqueous layer of magnetic liposomes and lipid soluble active drugs are incorporated in lipid layer of magnetic liposomes. Generally, two kinds of magnetoliposomes exist: one containing metal oxides ion the aqueous layer while other consisiting of meta oxides enveloped in lipid layer after being stabilized with laureth.

❖ **6.4 Magnetic Emulsion:-** [20]

Emulsion is a colloidal system consisting of two immiscible liquids (water and organic solvent) and being stabilized by polymers or surfactants known as emulsifying agents. Water compose oil in water type emulsion when it is based as continuous external phase while as internal dispersed phase, it constitutes reverse water in oil type emulsion. Magnetic emulsion is an emulsion type in which ferrofluids, containing the stable dispersion of magnetic nanoparticles, constitutes the internal phase.

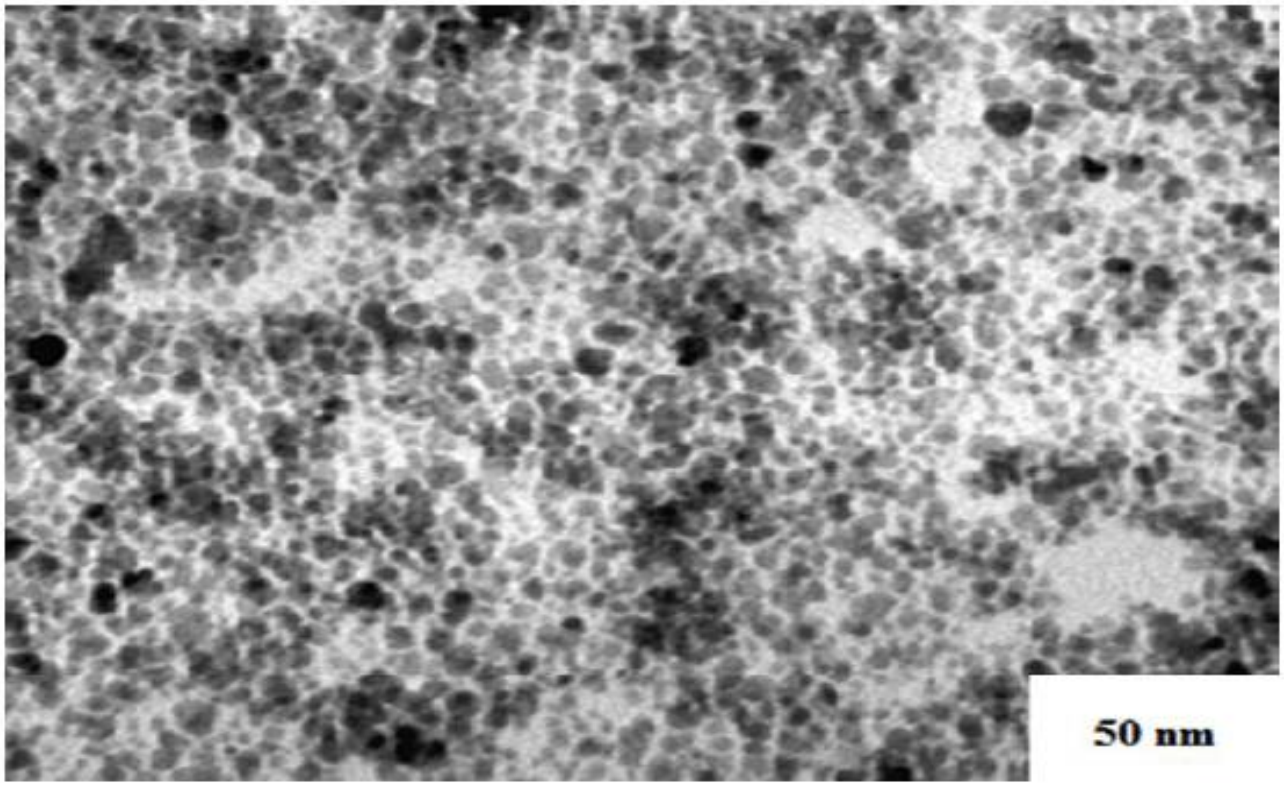

Figure 7: Transmission electron micrograph of the ferrofluids.

FACTORS AFFECTING MAGNETIC TARGETING OF DRUG [20]

1. Factors related to ferrofluids:

- Size of the particles in ferrofluid.
- Surface characteristics of particles.
- Concentration of the ferrofluid.
- Volume of the ferrofluid.
- Reversibility and strength of drug/ferrofluid binding (desorption characteristics).
- Access to the organism (infusion route).
- Duration or rate of injection/infusion.
- Geometry, strength and duration of the magnetic field application.

2. Physiological parameters related to patient (or animal):

- Size, weight and body surface of patient (or animal).
- Total blood volume.
- Cardiac output and systemic vascular resistance.
- Circulation time.
- Tumor volume and location.
- Vascular content of tumor.
- Blood flow in tumor.

APPLICATIONS OF MAGNETIC DRUG DELIVERY SYSTEM:

Magnetic drug delivery system since its origination has shown tremendous applications in biomedical and biophysical fields of science. We will discuss here some of its main contributions towards modern drug delivery.

❖ **7.1 Treatment of Tumors:-** [21]

Magnetic microspheres can be used in chemotherapy of anti-cancer drugs in their delivery to tumors e.g. doxorubicin. For such kind of site-specific targeting, magnetically modulated drug targeting systems have been successfully applied. Magnetic field in such cases is applied to concentrate the drug at tumor site thus eliminating systemic side effects.

Different rats suffering from sarcoma were assessed after giving both free doxorubicin and doxorubicin with magnetic microspheres. It was evaluated that rats treated with free doxorubicin had increased

tumor size while those treated with magnetic microspheres showed a significant 83 % decrease in the tumor size.

❖ **7.2 Targeting of Radioactive Compounds:-** [22]

Radioisotopes in therapeutic range can be delivered under magnetic field to target tissues. Dose can be increased rendering damage to the normal tissues with improved anti-tumor activity.

Selective radiation of the targeted tissues is carried out with the help of magnetic particles being coupled with different isotopes and an external magnetic field is applied to bind them.

❖ **7.3 Magnetic Hyperthermia:-** [23]

Magnetic hyperthermia has been established to destroy the diseased tissues with the help of elevated temperature as they are more sensitive to the temperature compared to the healthy tissues. The other advantage is its restriction to the diseased tissues only.

Recently liposomal nanoparticles have been established according to this mechanism as successful approach to the cancer therapy. Magnetic liposomes have also been prepared and studied for hyperthermia treatment of cancer through magnetic particles coated with phospholipids.

❖ **7.4 Diagnostic Applications:-** [24]

One of the modern and useful applications of magnetic delivery system is its diagnostic applications which involves;

➢ **a) In-vivo Applications:-**

With the development of NMR imaging technique, a new pharmaceutical class known as magnetopharmaceuticals has been established, providing following advantages. Improvement in distinguishing of diseased to normal tissue.
To determine normal function of organ.

➢ **b) In-vitro Applications:-**

Magnetic solid phase extraction method is used in isolation and determination of components and impurities from testing samples in large volume as compared to conventional extraction processes which are more time consuming.

❖ **7.5 Miscellaneous Applications:-** [25]

➢ **A. Cancer targeting:-**

Magnetism can play very important role in cancer treatment. Non invasive permanent magnetic field for one hour way found to induces lethal effects on several rodent & human cancers. Anticancer drugs reversibly bound to magnetic fluids & could be concentrated in locally advanced tumors by magnetic field that or arranged at tumor surface outside of the subject.

A magnetic fluid has been reported to which the drugs, cytokines & other molecule can be chemically bound to enable those agent to be directed within subject under the influence of high energy magnet. In one of such examples, epidoxorubicin was found to be safe in an experimental human kidney & in xerotransplaned colon carcinona model. Another example include magnetic doxorubicin in liposome, significant articancer effect in nude mice bearing colon cancer.

This method of delivery makes chemotherapy more effective by increasing the drug concentration at the tumor site, while limiting the systemic drug concentration. Anchary et al. had demonstrated capturing & aggregating magnetic microspheres at specific points in the vascular system which enable the access to microvessels which are not accessible by catheter & potentially blocked by magnetic targeting methods. This would be an efficient inexpensive method for creating an embolism to starve tumors, or to seal off arteriovenous malformations .

➢ **B. Magnetic fluid hyperthermia:-**

Hyperthermia is a promising approach to cancer therapy based on the heating of the target tissue to temperature between 42C & 46°C, thus generally reducing the viability of cancer cells & increasing their sensitivity to chemotherapy & radiation. Magnetic fluid hyperthermia is based on the fact that subdomain magnetic particles produce heat through various kinds of energy losses during application of an external AC magnetic field. If magnetic particles can be accumulated only in the tumor tissue, cancer specific heating is available, various biocompatible magnetic fluids , cationic magnetoliposomes and affinity magnetoliposomes have been used for hyperthermia treatment. Local hypothermic system was also found to be useful in tunor-bearing tongue.

There also exist the combination therapy which would induce hyperthermia treatment followed by chemotherapy or genetherapy. The approach involves use of magnetic carriers containing a drug to cause hyperthermia using the standard procedure, followed by the release of encapsulated drug that will act on the injured cells. It is anticipated that the combined treatement might be very efficient in treating solid tumor.

➢ **C. Improvement of Drug release:-**

Macromolecules such as peptides have been known to release only at a relatively low rate from a polymer controlled drug delivery system, this low rate of release can be improved by incorporating an electromagnetism triggerring vibration mechanism into the polymeric delivery devices with a hemispheric design, a zero-order drug release profile is achieved.

➢ **D. Other Applications :-**

Magnetically guided ferrofluid nanoparticles were used in retinal repair. Magnetically guided interstitial diffusion of the nanoparticles upto 20mm of the gel over periods of 72 hours was shown to be possible, thus demonstrating that essentially all points on the retinal surfaces are reachable from elsewere in the ocular interior.

Magnetic elements have been successfully used in gastrointestinal surgery for tissue fixation. which form hermetic seal after surgery & passibility of the gastrointestinal tract is maintained & the patient can able to eat immediately after operation.

Magnetic force used for gene delivery which results in low vector dose, the reduction in incubation time for transfection/transduction & possibility of gene delivery to otherwise non permissive cells.
Apart from their application in drug delivery, magnetism have sound applications in biosciences & biotechnologiges like immobilization, detection of biologically active compound & xenobiotic, detection, isolation & study of cells and cells organelles.

ADVANTAGES [26,27]:

Magnetic carriers localize the drug at targeted diseased sites, to accomplish following advantages:

- Efficient drug delivery to the target tissues (increase up to 60%).
- Reduced toxicity risk.
- Minimizes side effects risk.
- Free drug concentration in blood stream is reduced by factor of 100.
- Decline in normal cell tissue damage rate.
- Therapeutics responses in target organs at only one tenth of the free drug dose.
- Controlled drug release within target tissues for intervals of 30 min. to 30 hrs, as described.
- Avoidance of acute drug toxicity directed against endothelium and normal parenchymal cells.
- Adaptable to any part of the body.
- Reduces circulating concentration of free drug.
- Minimizes damage to the normal tissue cells and allows an effective treatment of regioned diseases.
- Delivery of 60% drug to the target tissue.
- Advantage of crossing micro-vacular barriers.
- Minimally reactive with blood components.
- Clinically non-toxic from the stand point of chemical and immunological agents.
- Capability of accommodating a wide variety of water soluble agents.

DISADVANTAGES [26,27]:

Due to these limitations magnetic drug targeting is likely to be approved only for very severe diseases that are refractory to other approaches. Such targeting is limited to specialized centers; and to antitumor, antifungal, transplantation, and CNS acting that is highly toxic or labile.

- Magnetic targeting is an expensive.
- In these, technical approach and requires specialized manufacture and quality control system.
- It needs specialized magnet for targeting, advance techniques for monitoring and trained personnel to perform procedures.
- A large fraction (40-60%) of the magnetite, which is entrapped in carriers, is deposited permanently in target tissues.
- It is an expensive, technical approach and requires specialized manufacture and quality control system.
- It needs specialized magnet for targeting, for monitoring, and trained personnel to perform procedures.
- Requires specialized microspheres and magnets.
- Treatment of multiple region requires sequential targeting.
- Demands new methods of noninvasive, localized monitoring term deposition of drug levels in target tissue.
- Tissue localization of microspheres results into long term deposition of magnetite at levels of 3.5mg/kg.
- Once the drug is released it is no longer attractive to the magnetic field.
- Possibility of embolization of the blood vessels due to accumulation of magnetic carriers.

FUTURE ASPECTS:

❖ **10.1 Magnetic Separation:-** [28]

Magnetic particles can be used to separate entities from their surroundings so that the surroundings can be purified or to concentrate the entities for further

study. This use is based on the difference in the susceptibility between a magnetically labeled entity and the surrounding medium. Examples of the use of this principle are magnetic cell sorting for cellular therapy and immunoassay (which is a process that measures and identifies a specific biological substance such as an antigen). Entities that can be labeled include cells, bacteria and some types of vesicles. The first step is to label the entities with the particles followed by the separation of the labeled entities by magnetic separation (Fig. 16). Usually coated particles will be used; the coating will help to bind the particles to the entities such as cells. Specific sites on the cell surfaces can be targeted for attachment by antibodies; this works as a labeling procedure since antibodies bind to their matching antigen. In order to separate out these labeled entities we can use a magnetic field gradient which can attract and "hold" the entities in specific regions, followed by removal of these entities. This method has been applied to the selection of tumor cells from blood as well as to isolate enzymes, DNA and RNA from various sources including body fluids.

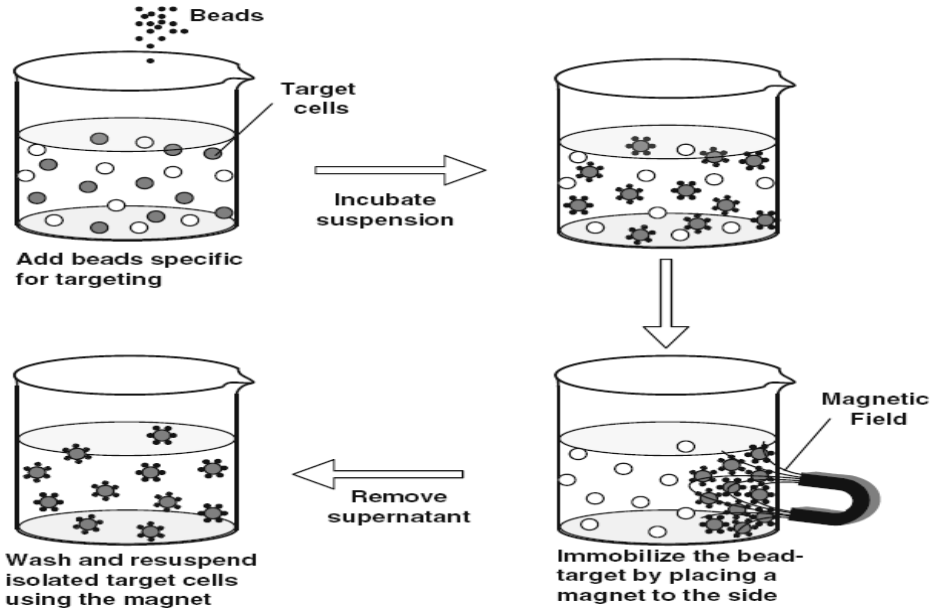

Figure 8: Magnetic Separation.

❖ **10.2 Gene Therapy:-** [29]

The recent emphasis on the development of non-viral transfection agents for gene delivery has led to new physics and chemistry-based techniques, which take advantage of charge interactions and energetic processes. One of these techniques which shows much promise for both in vitro and in vivo transfection involves the use of biocompatible magnetic nanoparticles for gene delivery. In these systems, therapeutic or reporter genes are attached to magnetic nanoparticles, which are then focused to the target site/cells via high-field/high-gradient magnets.

The technique promotes rapid transfection and, as more recent work indicates, excellent overall transfection levels as well. The advantages and difficulties associated with magnetic nanoparticle-based transfection will be discussed as will the underlying physical principles, recent studies and potential future applications.

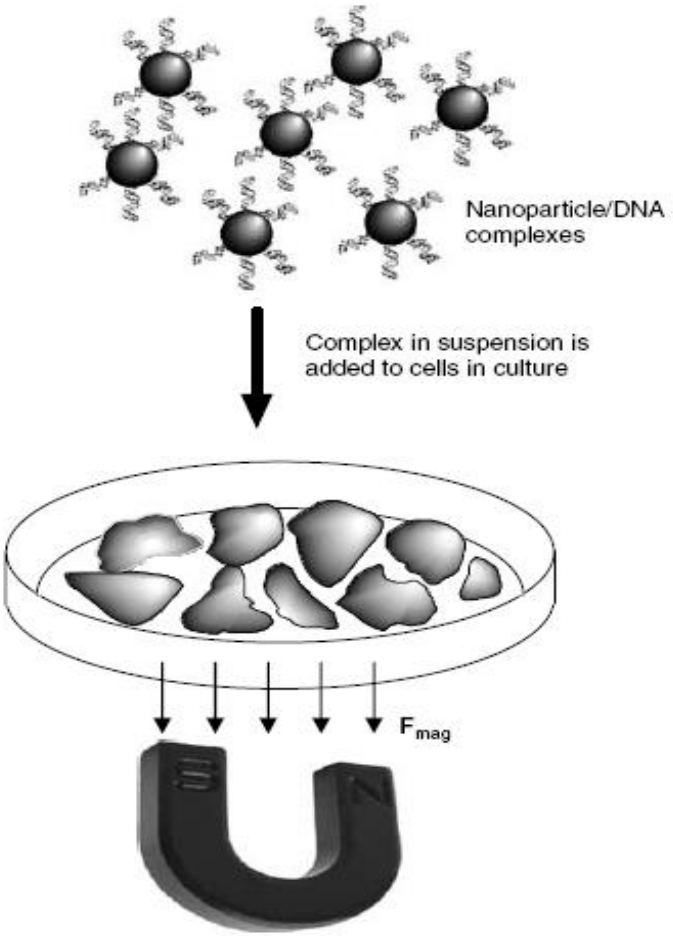

Figure 9:- Schematic representation of magnetic nanoparticle mediated gene delivery in vitro.

The vector is attached to magnetic nanoparticles, which are added to the cell culture. A high-gradient, rare-earth magnet is placed below the culture dish and the magnetic field gradient pulls the particles towards the magnetic field source, increasing the sedimentation rate of the particle/gene complex.

❖ **10.3 Magnetic Drug Delivery System in Oncology:-** [30]

Nanotechnology is an interdisciplinary field of technological developments on the nanometer scale offering comprehensive applications also to biomedicine. Engineering particles a several tens of nanometers in diameter has opened new possibilities for targeting cells within an organism either for diagnostic or therapeutic purposes. Magnetically-guided drug or gene targeting using magnetic nanoparticles is a promising approach for cancer chemotherapy and cancer gene therapy. The rationale behind these two treatment modalities is based on binding either chemotherapeutics or nucleic acids onto the surface of magnetic nanoparticles which are directed to and/ or retained at the tumor by means of an external magnetic field. Researchers have been studying magnetically-guided drug targeting since the late 1970's, however, magnetically-guided gene targeting has emerged as rapid and efficient approach in the beginning of the new millennium.

Magnetic nanoparticles have been explored predominantly in basic and translational research in the field of oncology although some of them have been already clinically approved as contrast enhancing agents for magnetic resonance imaging (MRI).

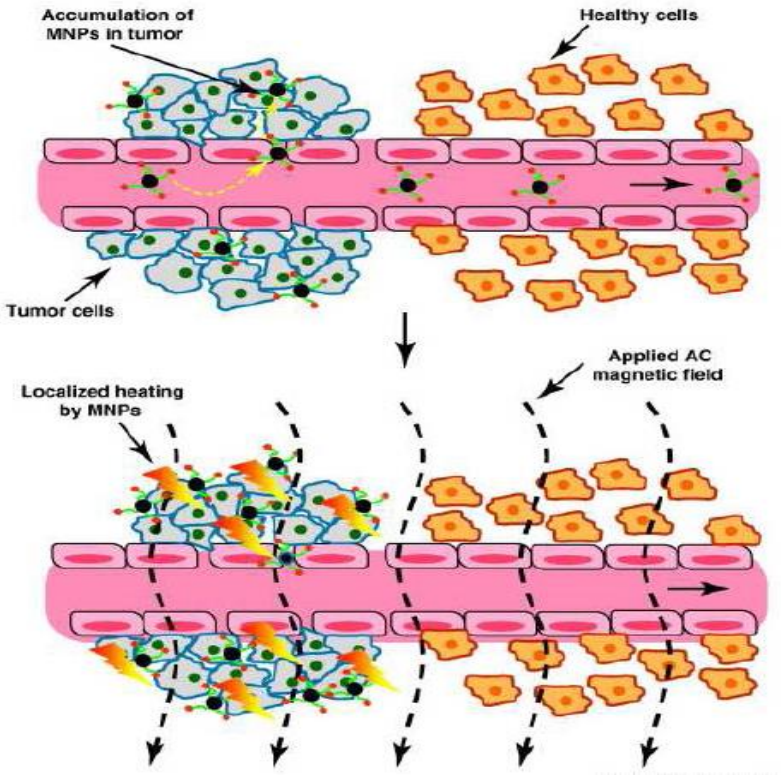

Figure 10:- Scheme of magnetic hyperthermia treatment of affected tissue; (a) accumulation of magnetic nanoparticles (MNPs) by the magnet at the tumor site; (b) exposition of tumor cells to an altering current (AC) magnetic field.

CONCLUSION:

Magnetically targeted drug delivery by particular carriers is an efficient method of delivering drug to localized diseased site such as tumors, also in order to increase the efficiency and reduce the unpleasant side effects. Also magnetic drug delivery improves the controllability, targeting and regulation of the drug.

In oral and other delivery system requires more dose to be given from which less amount of drug will reach to particular target area. While in this drug delivery less dose required because drug is delivered directly to the affected area.

By the use of strong magnetic field of the Ferrofluids, more characterization and long-term toxicity study, this will be utilized as an effective targeted drug delivery system.

Over the years, despite of a defect that magnetic drug delivery carriers constitute of a strong magnetic field, it has still proved to be an efficient drug delivery system by successfully achieving the selective targeting and controlled drug delivery. It's challenging future demands an extensive research area to combat the most chronic diseases of modern ages.

Thus, magnetic drug delivery system is more efficient and beneficial means of drug delivery.

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