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A Review On Magnetic Drug Delivery System By Using Nanoparticles.

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Abstract:-

A magnetic drug delivery system using nanoparticles is an advanced therapeutic approach that leverages the magnetic properties of nanoparticles for targeted drug delivery. In this system, biocompatible nanoparticles, typically coated with a drug and a magnetic material like iron oxide, are guided to specific tissues or cells using an external magnetic field. Once localized at the target site, the drug is released in a controlled manner, enhancing therapeutic efficacy while minimizing side effects. This method holds great promise in treating diseases like cancer, where precise drug delivery can significantly improve outcomes.

Magnetic drugs delivery system (MDDS) is an advanced technique that uses magnetic fields to target and deliver therapeutic agents to specific sites in the body. In this system, magnetic nanoparticles (often coated with drugs) are introduced into the bloodstream. By applying an external magnetic field, these particles can be guided to the desired location, enhancing the precision of drug delivery while minimizing side effects to surrounding tissues. MDDS holds great potential for treating localized diseases such as cancer, reducing systemic toxicity, and improving therapeutic outcomes.

Key words:- Magnetite (Fe3O4), Nanoparticles, Magnetic Targeting, Drug Encapsulation.

Introduction:-

One of the main problems of chemotherapy is the delivery of chemotherapeutic drugs to desired target locations for the treatment of localized disease with the least amount of systemic side effects. The biochemical distinctions between healthy and sick cells serve as the foundation for chemical strategies used to target chemotherapy drugs (1–5). The majority of the time, these variations are more quantitative than qualitative, which means that prescribed medications frequently have harmful side effects. By directing chemotherapeutic medicines to certain locations, it is possible to attain efficient local drug concentrations while lowering the systemic dose of a particular agent Clinical settings often involve substantial pharmaceutical dosages because of tissue-specific distribution or limited drug absorption.1, 2, Given that chemotherapy medications frequently have an unacceptable risk-benefit ratio, this factor becomes particularly crucial in oncology. The development of drug delivery systems based on nanoparticles and nanotechnology is among the most inventive applications of nanotechnology in medicine. Advances in nanosystem preparation in the field of nanomedicines have put pressure on scientists to develop intelligent functional materials that can meet unmet drug lease conditions.3–6..

Currently, the cornerstone of targeted cancer therapy is the development of highly selective and efficient inhibitors of signaling pathways that are altered or overexpressed in particular tumor cells compared to normal cells. Examples of well-known, fulfilling outcomes that have fully justified this approach are Herceptin and Gleevec. Limitations have been noted, though, and they are primarily associated with the tumor cells' genetic instability and adaptability. As a result, when an inhibitor effectively blocks a single, originally important pathway, tumor cells frequently arise that are able to circumvent this blockade by upregulating additional, parallel, or cross-communicating pathways.

Unfortunately, the patient's severe initial reactions to the medication are short-lived. after it became impossible to continue using the targeted agent as a treatment.

In recent years, various targeted delivery vehicles for enhanced medicine delivery have been created and evaluated in human trials and animal model studies [9]. Cytostatic drugs covalently bound to water-soluble polymers, polymeric nanoparticles, stabilized solid amorphous hydrophobic drug nanoparticles, micelles containing hydrophobic drugs, and liposomes containing both hydrophobic and hydrophilic drugs are a few examples of these delivery vehicles. Doxil a liposomal form of the cytostatic medication doxorubicin (DOX), was among the first systems to be introduced to the market. Despite the encouraging results, more efficient targeting strategies are still required to significantly increase the amount of these targeted 'nanomedicines' deposition and accumulation in tumor tissue.

Drugs are delivered precisely to a disease site using magnetic nanoparticles (MNPs) in magnetic drug delivery systems (MDDS), an innovative targeted therapeutic technique. By utilizing the body's reaction to external magnetic fields, this method allows for exact control over the location and release of drugs. It was first proposed in the late 1970s to use magnetic micro and nanoparticles as therapeutic medication carriers to target particular bodily locations. Wider and associates created magnetic micro- and nanoparticles that might be coupled with cytotoxic medications. After that, the patient receives an intravenous or intra-arterial injection of the drug/carrier complex. The medications are directed and concentrated at tumor sites using high-gradient, external magnetic fields produced by rare earth permanent magnets.The therapeutic agent is released from the magnetic carrier, either by enzymatic activity or by modifications to physiological parameters like pH, osmolality, or temperature, after the magnetic carrier has been concentrated at the tumor or another target in vivo. This increases the drug's absorption by the tumor cells at the target sites. Recently, similar ideas have been used to deliver therapeutic genes to particular targets in vivo.

Working Principle :-

Attaching medicinal chemicals, like chemotherapy medications, to magnetic nanoparticles is the fundamental idea of MDDS. After being injected into the bloodstream, these particles are directed to the intended location by means of an external magnetic field. The medicine may be released by a number of methods, including enzyme-triggered release or temperature-induced release, after the nanoparticles have been localized to the appropriate site.

Advantages Targeted :-

Drug Delivery: By facilitating extremely precise drug localization, MDDS lessens the systemic adverse effects that are frequently observed with traditional treatments.

Controlled Release: -

1.By modifying the external magnetic field, drug release can be precisely regulated, guaranteeing that the treatment is given over a predetermined amount of time.

2. Decreased Dosage: Lower dosages can be utilized to minimize toxicity and adverse effects by the drug's distribution directly to the affected location.

3.Non-invasive Guidance: Surgical procedures are not necessary because magnetic fields can be delivered non-invasively from outside the body.

Applications:-

MDDS has demonstrated potential for treating a number of illnesses, most notably cancer. Anticancer medications can be concentrated in tumors using this method without endangering healthy tissue. Additionally, it is used to treat infections, neurological conditions, and cardiovascular ailments.

Challenges:-

Even though MDDS has a lot of potential, there are still a number of obstacles to be addressed, such as the biocompatibility of magnetic nanoparticles, their possible toxicity, and the occasionally challenging task of precisely targeting them. The effectiveness of drug targeting may also be impacted by the difficulty of maintaining consistent magnetic fields in particular body parts.

Magnetic particle size:-

The size of magnetic drug particles, which are frequently utilized in drug delivery systems, usually falls between nanometers and micrometers. These particles' size is important since it affects their cellular uptake, bio distribution, and magnetic characteristics. In instance, magnetic nanoparticles (MNPs) typically range in size from 10 nm to 100 nm, which is tiny enough to avoid detection by the immune system and enable effective transport to target locations when guided by magnetic fields.

Smaller particles (less than 10 nm) may be quickly eliminated by the kidneys, whereas particles bigger than 200 nm may be removed by the reticuloendothelial system (RES) before they reach their target. Consequently, depending on the application, an ideal MNP size for drug delivery is typically thought to be between 10 and 200 nm. The impact of particle size on the pharmacokinetics and bio distribution of magnetic drug delivery system.

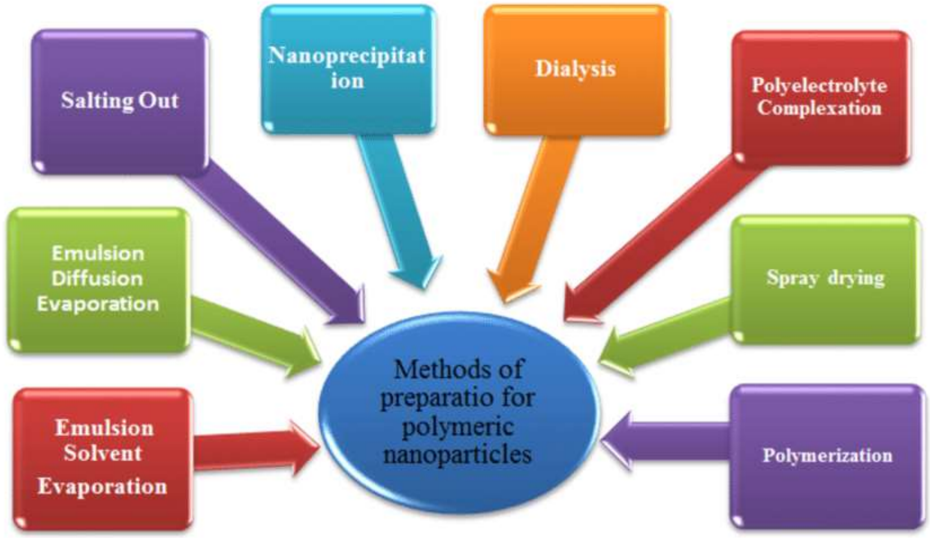

Fig.1. Methods of preparation of biochemical nanoparticles

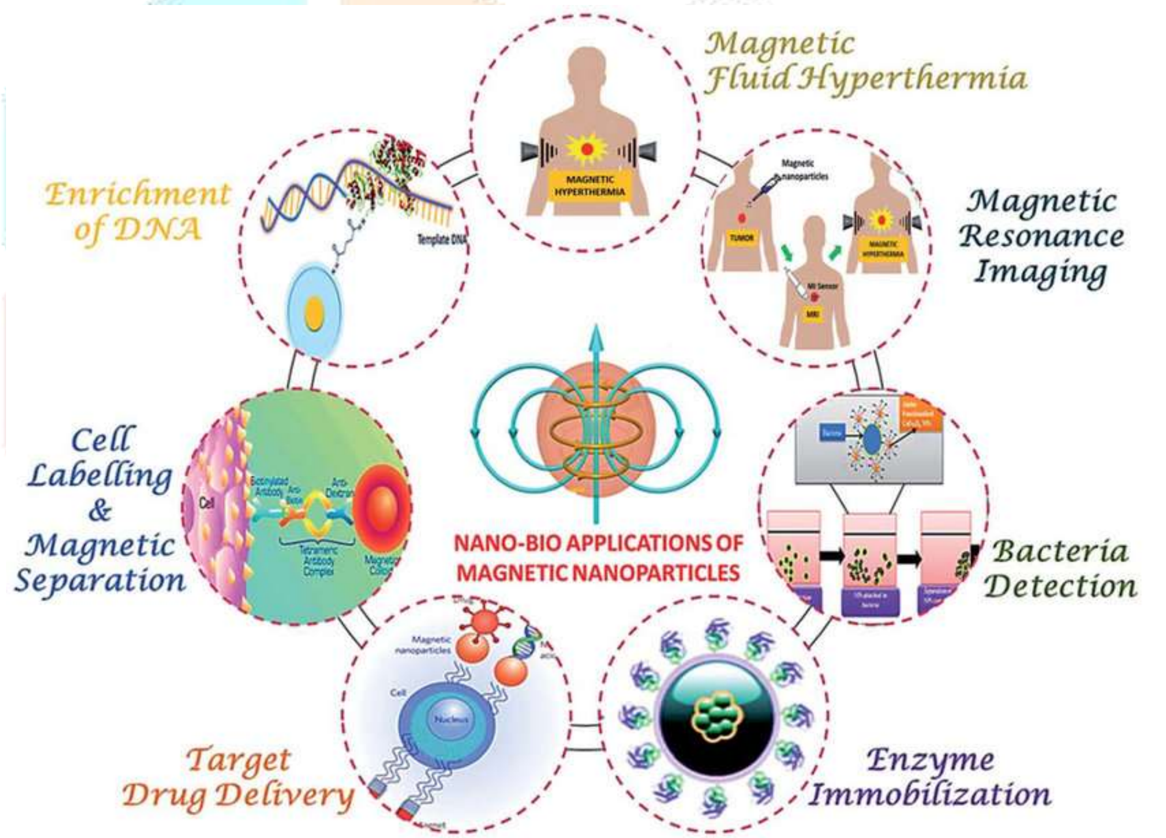

Fig. 2 Applications of magnetic Nanoparticles in biomedicine

Classification of Drug Targeting in Magnetic Drug Delivery Systems:

Therapeutic chemicals are guided to particular locations within the body by magnetic particles in magnetic drug delivery systems (MDDS), which are a targeted approach to medication delivery. The following categories apply to drug targeting in MDDS:

1.Passive Targeting :-

The increased permeability and retention (EPR) effect observed in tumors is one example of a natural biological process that causes medications to concentrate at specific areas in passive targeting. Because of leaky vasculature and inadequate lymphatic drainage at illness sites, the drug-carrying magnetic particles are introduced into the bloodstream and, because of their size and surface characteristics, preferentially aggregate in the target tissues. For instance, the EPR effect in solid tumors, where the permeable blood arteries permit nanoparticle entry and retention, causes the passive accumulation of nanoparticles in the case of tumor targeting.

2.Active targeting :-

Using ligands or antibodies on the surface of magnetic particles that bind selectively to receptors on target cells or tissues is known as active targeting. By strengthening the bond between the drug carrier and the target cells, this technique increases the drug delivery's selectivity and effectiveness. For instance, better selectivity for tumor areas is achieved by functionalizing super paramagnetic iron oxide nanoparticles (SPIONs) with antibodies that target cancer cell receptors, such as HER2.

3.Magnetically-Driven Targeting :-

One special feature of MDDS is magnetically-driven targeting, in which drug-loaded magnetic nanoparticles (MNPs) are guided to particular locations by an external magnetic field. External magnets positioned close to the target region control the magnetic particles, enabling localized medicine administration and fewer systemic adverse effects. For instance, SPIONs have been extensively researched in preclinical mode for localized drug delivery to malignant areas under the guidance of an external magnet.

4.Stimuli-Responsive Targeting :-

This technique involves designing magnetic nanoparticles to release their drug load in response to particular stimuli, like variations in temperature, pH, or magnetic field. Only when the target environment or an outside event triggers the drug's release does it become active during systemic circulation. Example: Drugs are released by thermoresponsive polymers coated on SPIONs when they are heated locally by alternating magnetic fields.

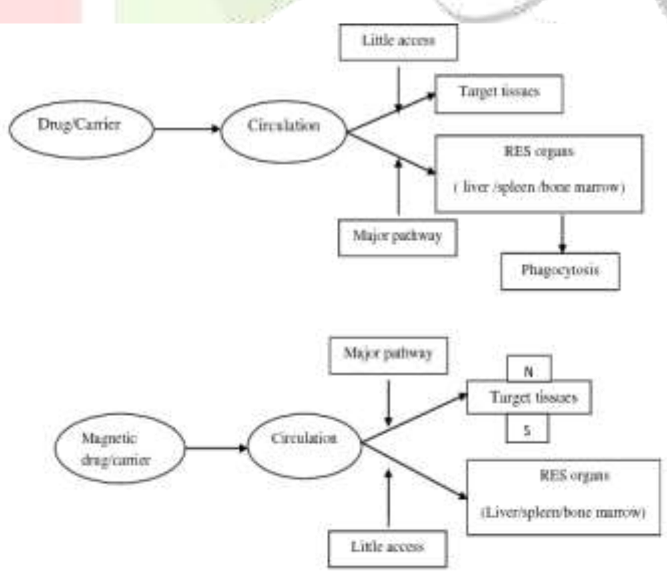

Fig. 3 Principles of Magnetic Drug Targeting

Solubility of magnetic drugs delivery system particle :-

The effectiveness of magnetic drug delivery system (MDDS) particles is largely dependent on their solubility. To target medication delivery under an external magnetic field, these systems frequently use magnetic nanoparticles (MNPs), which are usually made of minerals like iron oxide (magnetite, FeO_4, or magnetite, γ-FeO_3). Drug release, bioavailability, and interactions with biological systems are all impacted by these particles' solubility.

Important Elements Affecting MDDS Solubility:-

1.Surface Coating and Particle Size:-

Because of their larger surface area, smaller nanoparticles typically have higher solubility. Surface coatings such as surfactants or polymers (like PEG) increase solubility and biocompatibility, inhibit aggregation, and promote blood circulation. Additionally, coatings

regulate medication release by adjusting the solubility of particles in the biological environment. Composition.Although iron oxide MNPs are typically hydrophobic and poorly soluble in water, they can be made more soluble in water by coating them with hydrophilic materials or employing other magnetic materials. For instance, to improve solubility and stability, fertile can be functionalized with substances like silica or dextran.

2.pH Sensitivity:-

To enable regulated and targeted release, certain MNPs are made to be soluble or release medications only at particular pH values (such as in acidic tumor settings). This behavior is influenced by surface changes or pH-responsive coatings.

3.Biodegradability :-

The solubility of magnetic particles in physiological circumstances is influenced by their long-term stability and biodegradability. For example, magnetic particles are frequently encapsulated in biodegradable polymers like PLGA (poly(lactic-co-glycolic acid)), which improve solubility while guaranteeing slow breakdown. The solubility of magnetic drug delivery systems and their overall therapeutic potential are largely determined by these parameters.

MAGNETIC NANOPARTICLES/CARRIERS :-

Magnetic nanoparticles (MNPs) are particles that may be controlled by applying magnetic fields; they are usually between 1 and 100 nanometers in size. They are frequently employed as carriers in imaging, drug administration, and other biomedical applications. In order to prevent aggregation and improve stability in biological contexts, these nanoparticles are frequently made of magnetic materials like iron oxide (FeO_4 or γ-FeO_3) coated with biocompatible compounds. By enabling targeted administration to particular locations, the magnetic features lessen side effects and increase therapeutic effectiveness.

By applying an external magnetic field, MNPs can be functionalized with therapeutic substances and guided to the intended location in the body for medication administration. This method minimizes systemic diffusion while increasing medication concentration at the target region. Similar to this, magnetic nanoparticles are employed in hyperthermia therapy, which helps kill malignant cells by causing localized heating by an alternating magnetic field. Furthermore, because MNPs can improve image resolution, they are used as contrast agents in magnetic resonance imaging (MRI), which improves diagnostic capacities.

APPROACHES TO MAGNETIC DRUG TARGETING:-

Using magnetic fields to guide medicinal drugs to particular bodily locations is known as magnetic drug targeting, or MDT. By concentrating medications at the intended site, this method has drawn interest due to its potential to lessen systemic side effects. Magnetic drug targeting can be approached in a variety of ways, each with its own tactics and difficulties. Here is a summary of the main techniques.

1.Magnetic Nanoparticles (MNPs) as Drug Carriers:-

One of the primary approaches is the use of magnetic nanoparticles (MNPs), typically iron oxide-based, as carriers for drugs. These MNPs are functionalized with therapeutic agents, which can be steered to a specific location using an external magnetic field. Once the drug-laden nanoparticles accumulate at the target site, the drug can be released either passively (via degradation of the nanoparticle or diffusion) or actively (stimulated by heat, pH changes, or enzymes). These systems have the benefit of being biocompatible and offering controlled release mechanisms.

2. External Magnetic Field Guidance:-

An alternative strategy involves directing magnetic drug carriers through the circulatory system to particular tissue sites using external magnetic fields. To guide the MNPs to specific areas, such tumors, this method needs powerful, localized magnetic fields. High-gradient magnetic field systems or Helmholtz coils are frequently used in experimental setups to regulate the flow of MNPs throughout the body.

3.Hyperthermia-Enhanced Drug Delivery:-

When exposed to an alternating magnetic field, magnetic nanoparticles are utilized in hyperthermia-based MDT to both transport medications and produce localized heating. Two uses for this targeted heating are to increase tissue permeability (for better drug delivery) and use heat to kill tumor cells directly. If the MNPs are made to react to temperature changes, the heat produced may also cause the release of drugsriers.

4.Magnetic Resonance Imaging (MRI)-Guided MDT:-

A theranostic strategy is provided by combining magnetic resonance imaging (MRI) and MDT, in which MNPs are utilized for both real-time imaging of the target region and medication delivery. This enables accurate tracking and observation of the MNPs as they approach the target while being influenced by an external magnetic field. This dual-purpose system gives input on drug distribution and increases targeting precision.

5.Immuno-Magnetic Targeting:-

Using ligands like antibodies that bind to target cells (like cancer cells) precisely, MNPs are functionalized in this manner. Magnetic fields are subsequently used to direct the MNP-antibody complexes to the intended spot. By combining the physical control provided by magnetic fields with the specificity of molecular targeting (via antibodies), this technique increases the possibility that the medicine will reach and have an impact on the specified region.

Conclusion:-

Nanoparticle-based magnetic drug delivery systems represent a promising advancement in targeted therapy. By leveraging the unique properties of nanoparticles, such as their small size and surface functionalization, these systems enable precise drug delivery to specific sites, reducing systemic side effects and improving therapeutic efficacy. The incorporation of magnetic fields allows for enhanced control over drug release and localization, making it particularly useful in treating cancers and other localized diseases.

However, challenges remain, including ensuring biocompatibility, scalability of production, and the need for thorough clinical evaluation. Future research should focus on optimizing these systems for specific applications, exploring novel materials, and understanding the long-term impacts on human health. Overall, the integration of nanoparticle technology with magnetic guidance holds significant potential for revolutionizing drug delivery methods in medicine.

Reference :-

1.Widder KJ, Senyel AE, Scarpelli GD. Magnetic microspheres: a model system of site specific drug delivery in vivo. Proc Soc Exp Biol Med. 1978 Jun;158(2):141-6. Doi: 10.3181/00379727-158-40158. PMID: 674215.

2.Ruiz-Hernández E, Baeza A, Vallet-Regí M. Smart drug delivery through DNA/magnetic nanoparticle gates. ACS Nano. 2011 Feb 22;5(2):1259-66. Doi: 10.1021/nn1029229. Epub 2011 Jan 20. PMID: 21250653.

3.Klostergaard J, Seeney CE. Magnetic nanovectors for drug delivery. Maturitas. 2012 Sep;73(1):33-44. Doi: 10.1016/j.maturitas.2012.01.019. Epub 2012 Mar 7. PMID: 22402027.

4.Martel S. Magnetic therapeutic delivery using navigable agents. Ther Deliv. 2014 Feb;5(2):189-204. Doi: 10.4155/tde.13.147. PMID: 24483196.

5.Dobson, Jon. (2006). Dobson, J. Magnetic nanoparticles for drug delivery. Drug Develop. Res. 67, 55-60. Drug Development Research. 67. 55 – 60. 10.1002/ddr.20067.

6 .Shubayr, N. et al. (2022). “Magnetic nanoparticles for medical applications: A review.” Materials Science and Engineering C, 123, 112023.

7.Pankhurst, Q.A., Connolly, J., Jones, S. & Dobson, J. (2003). “Applications of magnetic nanoparticles in biomedicine.” Journal of Physics D: Applied Physics, 36(13), R167–R181.

8.Alexiou, C., et al. (2000). “Targeted tumor therapy with ‘magnetic drug targeting’.” FEBS Letters, 425(3), 299-305.

9.Kumar, C. S. S. R., Mohammad, F. (2017). Magnetic nanomaterials for hyperthermia-based therapy and controlled drug delivery. Journal of Controlled Release, 152(3), 65-89.

10. Maeda, H. (2010). Tumor Selective Delivery of Macromolecular Drugs via the EPR Effect: Background and Future Prospects. Bioconjugate Chemistry, 21(5), 797–802. Doi:10.1021/bc100070g

11. Dobrovolskaia, M. A., & McNeil, S. E. (2007). Immunological properties of engineered nanomaterials. Nature Nanotechnology, 2(8), 469–478. Doi:10.1038/nnano.2007.223

12. Pankhurst, Q. A., Connolly, J., Jones, S. K., & Dobson, J. (2003). Applications of magnetic nanoparticles in biomedicine. Journal of Physics D: Applied Physics, 36(13), R167. Doi:10.1088/0022-3727/36/13/201

13.Reddy, L. H., Arias, J. L., Nicolas, J., & Couvreur, P. (2012). Magnetic nanoparticles: Design and characterization, toxicity and biocompatibility, pharmaceutical and biomedical applications. Chemical Reviews, 112(11), 5818–5878. Doi:10.1021/cr300068p

14. Kumar, C. S. Shammad, F. (2011). Magnetic nanomaterials for hyperthermia-based therapy and controlled drug delivery. Advanced Drug Delivery Reviews, 63(9), 789-808.

15.Gupta, A. K., & Gupta, M. (2005). Synthesis and surface engineering of iron oxide nanoparticles for biomedical applications. Biomaterials, 26(18), 3995-4021.

16.Laurent, S., Dutz, S., Häfeli, U. O., & Mahmoudi, M. (2011). Magnetic fluid hyperthermia: Focus on superparamagnetic iron oxide nanoparticles. Advances in Colloid and Interface Science, 166(1-2), 8-23

17.Veiseh, O., Gunn, J. W., & Zhang, M. (2010). Design and fabrication of magnetic nanoparticles for targeted drug delivery and imaging. Advanced Drug Delivery Reviews, 62(3), 284-304.

18Sun, C., Lee, J. S., & Zhang, M. (2008). Magnetic nanoparticles in MR imaging and drug delivery. Advanced Drug Delivery Reviews, 60(11), 1252-1265..

19.Laurent, S., Forge, D., Port, M., Roch, A., Robic, C., Vander Elst, L., & Muller, R. N. (2008). Magnetic iron oxide nanoparticles: Synthesis, stabilization, vectorization, physicochemical characterizations, and biological applications. Chemical Reviews, 108(6), 2064–2110.

20.Pankhurst, Q.A., Connolly, J., Jones, S.K., & Dobson, J. (2003). Applications of magnetic nanoparticles in biomedicine. Journal of Physics D: Applied Physics, 36(13), R167-R181.

21.Shapiro, B. (2009). Magnetic drug targeting in the circulatory system: Mathematical models and applications. Journal of Magnetism and Magnetic Materials, 321(10), 1594-1600.

22.Laurent, S., Dutz, S., Häfeli, U.O., & Mahmoudi, M. (2011). Magnetic fluid hyperthermia: Focus on superparamagnetic iron oxide nanoparticles. Advances in Colloid and Interface Science, 166(1-2), 8-23.

23.Bulte, J.W.M., & Modo, M.M. (2017). Design and Applications of Nanoparticles in Biomedical Imaging. Springer International Publishing

24.Veiseh, O., Gunn, J.W., & Zhang, M. (2010). Design and fabrication of magnetic nanoparticles for targeted drug delivery and imaging. Advanced Drug Delivery Reviews, 62(3), 284-304.