IJPPR
INTERNATIONAL JOURNAL OF PHARMACY & PHARMACEUTICAL RESEARCH
An official Publication of Human Journals
ISSN 2349-7203
HUMAN

Human Journals
Review Article
June 2023 Vol.:27, Issue:3

Magnetic Nanoparticles: A Novel Methods in Drug Delievery

IJPPR
INTERNATIONAL JOURNAL OF PHARMACY & PHARMACEUTICAL RESEARCH
An official Publication of Human Journals
ISSN 2349-7203
HUMAN

Govind Sukase*, Jaydeep Pawar, Meghana Raykar, Sunil Nirmal

Dept .of Pharmaceutics, HSBPVT's, GOI, Faculty of Pharmacy, Kashti, Tal-Shrigonda, Dist-Ahmednagar, 414701, Maharashtra, India.

Submitted: 24 May 2023
Accepted: 31 May 2023
Published: 30 June 2023

HUMAN JOURNALS
www.ijppr.humanjournals.com

Keywords: Chemical properties, Physical properties, Magnetic nanoparticles, Diagnosis, and Treatment

ABSTRACT

In scientific applications, magnetic nanoparticles have proven their incredible potential. The improvement of specific medical activities of MNP has been advanced by technological advancements in the production and modification of nanoscale substances. The essential chemical and physical characteristics of MNP that are important for medical applications were included. MNP's physicochemical properties are mostly related to its pharmacokinetics and cell adsorption. extreme magnetic susceptibility, high coercivity, and non-toxicity. Superparamagnetic The expanding range of research publications on magnetic materials demonstrates increased interest within the scientific community at large. The synthesis of magnetic materials with desired size, shape, chemical composition, and surface chemistry used to undergo significant development. The coating helps magnetic materials achieve physical and chemical stability. The discoveries on the design and synthesis of magnetic materials intended for biological applications are summarized in the review article that is being presented. We highlight the use of magnetic materials in the separation and preconcentration of various chemicals and cells, as well as their applications in therapy and diagnosis.

INTRODUCTION

Magnetic nanoparticles are of great interest to researchers in a wide range of applications, including magnetic fluids in biotechnology and biomedicine, magnetic resonance imaging, data storage, and environmental cleaning. Even if several viable methods for their production have been found, the ability of the particles to remain stable under a variety of different settings is essential for the successful application of magnetic nanoparticles in the aforementioned sectors. The bulk of the applications that are being investigated for the particles work well when the size of the nanoparticles is below a threshold value, which varies depending on the material but is frequently between 10 and 20 nm. Such tiny particles frequently combine in order to absorb the energy associated with them because of their large surface area to volume ratio. Pure metallic nanoparticles are also incredibly chemically active. When exposed to oxygen, they swiftly oxidize and often lose their magnetic disposability. In order to prevent deterioration of the naked magnetic nanoparticles during or after production for a variety of applications, it is crucial to develop defense mechanisms. These strategies involve applying an inorganic layer of coating, like silica or carbon, or attaching or grafting organic species, like surfactants or polymers. Notably, depending on the intended purpose, the protective shells frequently work to further functionalize the nanoparticles, such as by combining them with other nanoparticles or various lagans, in addition to stabilizing them.[1]

The application of functionalized nanoparticles in bio labelling, bio separation, and catalysis is very promising. Particularly in liquid-phase catalytic reactions, such microscopic and magnetically separable particles may be used as quasi-homogeneous systems that combine the advantages of high reactivity, considerable dispersion, and straightforward separation. After a brief overview of the special magnetic properties of nanoparticles, we will mainly focus on recent developments in the production of magnetic nanoparticles and several strategies for protecting the particles against oxidation and acid erosion. We will briefly discuss additional functionalization and uses for these magnetic nanoparticles in bio separation and catalysis. If readers are interested in a more in-depth study of the physical properties and behavior of these magnetic nanoparticles or biomedical and biotechnology uses, they are directed to specific applications[2]. Magnetic nanoparticles (MNPs) with sizes ranging from 1 to 100 nm have made important contributions to science and technology during the past 20 years. They differ from their bulk counterparts due to unique characteristics such as a high surface to volume ratio and size-dependent magnetic properties. Numerous industries, including data storage, spintronics, catalysis, neurological stimulation, and gyroscopic sensors, have shown a great deal of interest in MNPs. This work discusses the magnetic anisotropy and saturation magnetization of MNPs, among other physical properties.[3]

Advantages of Magnetic Nanoparticles:[2–4]

- In addition to detection, a magnetic particle's inherent ability to respond to a static or alternating magnetic field includes energy transfer, manipulation by a gradient in the magnetic field (separation of magnetic carriers), and additional local magnetic fields (MRI).
- Magnetic hyperthermia has the benefit of allowing the heating to be focused on the tumor region. Furthermore, because nanoparticles can absorb substantially more power at acceptable AC magnetic fields, they are chosen over multidomain (micron-sized) magnetic particles.
- Since particle size and shape have a significant impact on temperature, it is crucial to have well-defined synthetic pathways that can produce uniform particles.

TYPES OF MAGNETIC NANOPARTICLES:[3–6]

1. Oxides: ferrite

The magnetic nanoparticles that have received the most research to date are ferrite particles. Since they only exhibit their magnetic behavior when an external magnetic field is applied, super paramagnetic ferrite nanoparticles, which are smaller than 128 nm, avoid self-agglomeration. Remanence returns to zero when the external magnetic field is turned off. The surface of ferrite nanoparticles is frequently altered by surfactants, silicones, or phosphoric acid derivatives to boost their stability in solution, just like non-magnetic oxide nanoparticles.[5]

2. Metallic with a shell

Magnetic nanoparticles' metallic cores can become inert through moderate oxidation, surfactants, polymers, and precious metals. Co nanoparticles develop an anti-ferromagnetic Co O layer on their surface when exposed to oxygen. Recently, research has examined the synthesis and exchange bias impact in these gold-coated Co core, Co O shell nanoparticles. Recently, it has been possible to create nanoparticles with a magnetic core formed of either elementary iron or cobalt and a nonreactive grapheme shell. When contrasted to ferrite or elemental nanoparticles, the benefits are:[6]

- Higher magnetization
- Higher stability in acidic and basic solution as well as organic solvents
- Chemistry on the grapheme surface via methods already known for carbon nanotubes.

Magnetism:

Has two sources electrical currents and the magnetic spin moments of basic subatomic particles like electrons. Since each electron's magnetic spin moment cancels out the others, the arrangement of the electrons that make up a substance normally inhibits the creation of any typically magnetizable particles. The magnetic spin moments of the basic subatomic particles occasionally spontaneously align to generate a normal magnetizable of the whole or portion of the material. Magnetism in various materials takes many forms, such as ferromagnetism and Para magnetism. When a magnetic field is applied, materials with an unpaired electron display paramagnetic behavior, which is characterized by the development of internal-induced magnetic domains. As a result, gradients in an external magnetic field are attracted to by paramagnetic materials. The typical magnetizable of a ferromagnet can simultaneously separate into smaller sections if the material's diameter exceeds a certain value, DC (magnetic domains). Ferromagnetic materials are also impacted by the Curie temperature (TC). Each material has a unique TC, which establishes the temperature at which external magnetism can be used to replace permanently magnetizable materials.[7,8]

Nanoparticles' magnetic properties

Component behavior in the presence of an external magnetic field is significantly influenced by susceptibility and permeability. When a substance is exposed to an external magnetic field (H), its susceptibility () is determined by how magnetic that material is (M):[8]

$$\mathbf{M = \chi H}$$

The permeability represents the magnetic induction (B) change brought on by an external magnetic field (B=H). All materials are classified into a number of classifications mostly based on their susceptibility to magnetic fields, with materials with high permeability exhibiting low resistance when exposed to magnetic fields.33

Diamagnetic:

These materials generate a magnetic moment that is susceptible to and antiparallel to the external field when there is an external magnetic field present. Consequently, they are less susceptible (-10-6 to 10-3). When the external field is taken away, the spins return to their original positions and lose their magnetic qualities. Copper, quartz (SiO2 and water), silver, wood, and the vast majority of natural compounds are examples of diamagnetic materials. This substance behaves usually in filled electronic subshells.[9]

Components that are paramagnetic exhibit magnetic fields that are susceptible to externally applied fields. These work well and are prone to a number of (10-5 to10-3). When the external field is eliminated, they lose their magnetic moment. Aluminum, magnesium, oxygen, and lithium all have paramagnetic properties.[10]

Ferromagnetic:

Materials that are considered to be magnets, or ferromagnetic, have a sizable and effective susceptibility. How ferromagnetic materials are affected by external fields, temperature, and atomic structure. When two other items are considered, their magnetic homes work even in the absence of a magnetic field. After applying a strong magnetic field, the substance's spins are actually aligned with the magnetic field. The greatest level of magnetization, known as saturation magnetization, has now obtained. Full magnetization is diminished when the size of the zone is reduced because the spins revert to their original directions. However, the magnetic moments of these materials hold steady even in the absence of a field.[11,12]

Table 1: Frequently used compounds to surfacely modify magnetic NPs[12]

Modified compounds	Advantages	Applications
Glucan	Excellent stability and increase in vivo circulation time	Drug vectors
PEI	Good biocompatibility	Gene and drug vectors
Chitosan	Good stability and biocompatibility	Vector, thermotherapy
FA	Good biocompatibility, essential small biological molecule vitamin for the human body	Targeted receptors, diagnosis, and treatment of tumors (breast cancer, cervical cancer, and ovarian cancer)
Gold	Biocompatibility will provide optimize property and magnetism for biological uses	Tumor diagnosis and MRI
PEG	Improved water solubility of NPs, phagocytosis, and increased blood circulation time	MRI, tumor diagnosis, and treatment
Polyvinyl alcohol	Improved stability and reduced particle aggregation	MRI, vectors, and bio separation

Methods of Preparation:

A large proportion of the studies on MNPs that have been published in recent years have described efficient approaches to obtain shape-controlled, fairly stable, and MNPs with a narrow size distribution. A number of well-known processes, including microemulsion, sonochemistry, microwave assistance, thermal decomposition, chemical vapor deposition, combustion synthesis, co-precipitation, carbon arc, solvothermal, and laser pyrolysis synthesis, have been proposed for the production of magnetic nanoparticles.[13,14]

Synthesis of Magnetic Nanoparticles:

In the past, producing magnetic nanoparticles was an essential step in any research aimed at enhancing their properties and figuring out whether they had any practical use. Since many of these nanomaterials are now widely available commercially and don't require specialized teams or equipment to make them, experiment repeatability is improved. Even said, producing nanoparticles is still a critical step in research aimed at further exploration and is certainly important for the production of innovative particle kinds and synthesis techniques.[15]

Chemical groups based on compounds (usually oxides) of iron, cobalt, nickel, and other elements that typically combine many different metals can be used to classify materials that are typically used to create magnetic components. These mixes often contain elements with strong bases in barium, strontium, copper, and zinc. Another element of magnetic nanoparticles is the group of metallic nanoparticles and nanoalloys. Naturally, the surface treatments of nanoparticles have a significant impact on their synthesis. The coating's main goals are to boost the stability and solubility of nanoparticles, increase their biocompatibility and target-specificity, and guard against toxic buildup, oxidation, corrosion, and toxicity.[16]

It is evident from a large number of recently published reviews that problems with the production of magnetic nanoparticles have attracted a lot of attention recently. Therefore, the text that follows focuses mainly on the stated manufacturing of magnetic nanoparticles, which are generally employed for medical and biological applications.[17]

Magnetic Nanoparticles Based on Iron:

Magnetic iron oxide nanoparticles are materials with the required magnetic properties and are frequently employed in biomedical applications. Significant benefits for magnetic iron oxide nanoparticles include cheaper production costs, adequate physical and chemical stability, biocompatibility, and environmental safety. Particular emphasis is placed on these benefits' affordability, stability, and compatibility. It is vital to consider the likelihood of their unique biological applications, such as magnetic separation, focused drug administration, MRI, magnetic fluid hyperthermia and chemoablation, and biosensing. Wu et al., as well as other authors, have meticulously assembled a lengthy list of numerous techniques for the creation and surface modification of magnetic nanoparticles that are mostly based on iron.[18,19]

A critical phase in the synthesis process is the modification of the floor of magnetic nanoparticles, which impacts their properties and the stability of colloid suspensions. The materials used for coating should have a strong affinity for the iron oxide core while still matching the requirements for particles in terms of their function. Numerous procedures of surface alterations had been introduced thanks to McCarthy and Weissler. A technique for the exact, reproducible synthesis of contemporary nanoparticles with control over the size, distribution, and hydrodynamic diameter of the magnetic core was published by Monet et al. These nanoparticles' major component is a maghemite core produced by covalently joining dextran macromolecules with aminopropyl silane molecules and Schiff's base. This approach is not the same as the earlier and more widely used one-step process, which depended on the coprecipitation of iron (II) and iron (III) precursors in the alkaline aqueous solutions of the hydrophilic macromolecule. A variation of this method that produces products with greater dispersion and uniform size is using ultrasonic-assisted chemical coprecipitation, as was the case in the case of Fe3O4 nanosized cubic particles with an excessive quantity of crystallinity.[20]

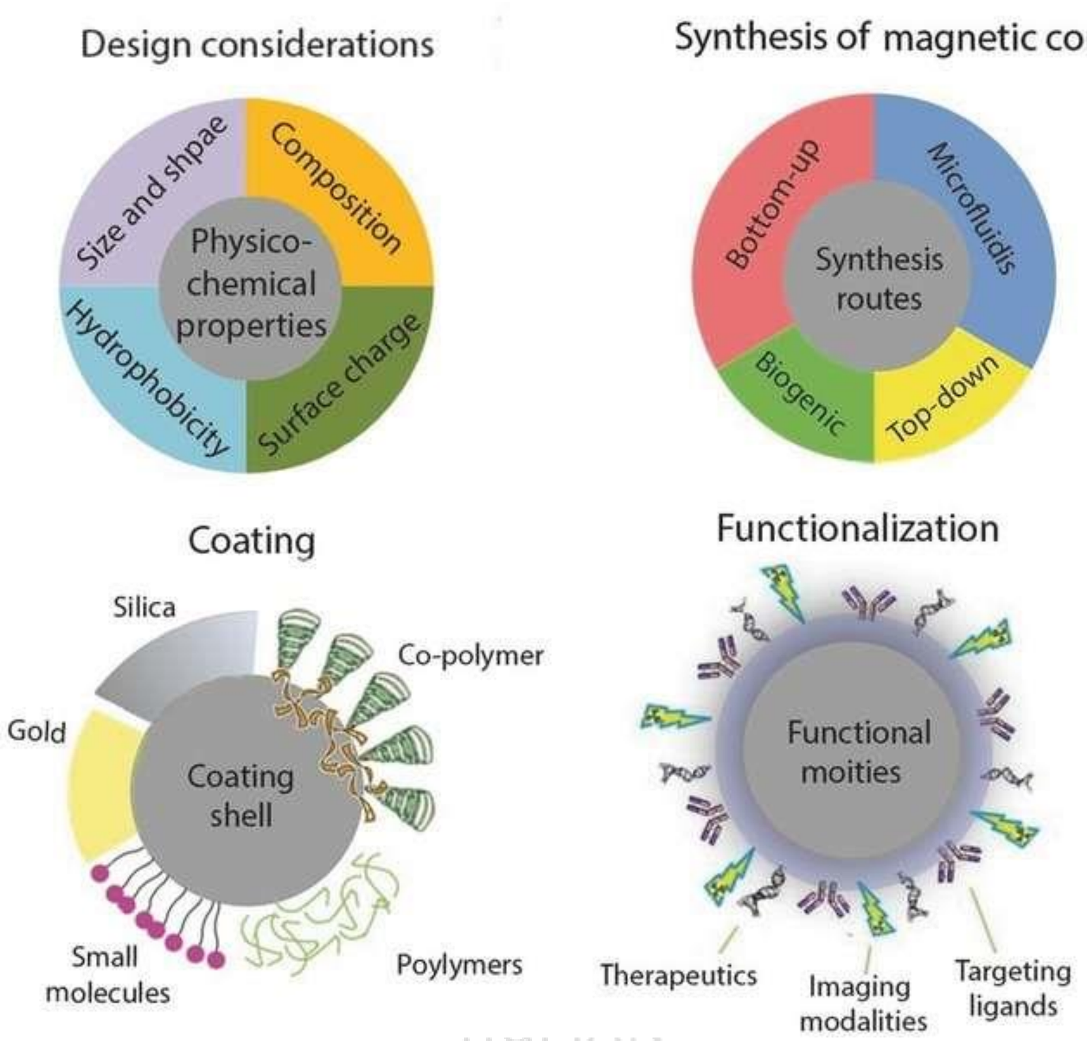

Figure 1: The scheme of magnetic particles design workflow [21]

Any other prospective nanomaterial with superparamagnetic characteristics desired for MRI is denoted by magnetic nanoparticles made of steel alloys or bimetallic materials. Different techniques, such as solution phase synthesis or vacuum deposition, have been used to create iron-platinum (FePt) nanoparticles useful for biomedical applications [39]. By using oleic acid and oleyl amine as stabilizers together with the reduction of platinum acetylacetonate and the breakdown of Fe(CO)5, monodispersed and size-tunable FePt nanoparticles may be structured. Such nanoparticles exhibit the ability to bind DNA and proteins and have proved stable in cell culturing medium or phosphate buffered saline.[21,22]

Cobalt-based magnetic nanoparticles are far less frequently synthesized and used in biological applications than iron because of cobalt's toxicity. There are just a few publications devoted to the teaching and/or theoretical bio use of magnetic nanoparticles of cobalt, with the exception of the aforementioned metal-doped iron oxides with formula CoFe2O4 and metallic alloy magnetic nanoparticles (Fe12Co88, Fe40Co60, and Fe60Co40). Theoretical biomedical applications as drug carriers have been developed using commercially available carbon-coated cobalt nanoparticles that have been functionalized with dendrons or polymers functionalized with polyhydroxy, polyamine, or PEG2000. Unfortunately, the application of modified nanoparticles in vitro or in vivo has not been explained, nor have any testing for toxicity been presented. The initial materials were described as the fabrication of magnetic cobalt nanoparticle dispersions in biocompatible poly (dimethyl siloxane), di cobalt octa carbonyl Co2(CO)8, and block copolymer. These nanoparticles offer hope for the treatment of retinal detachments. Similar to how they had not previously been tested for biocompatibility or toxicity, the particles used in the other investigation had been similarly manufactured. Similar to this, cobalt/silica carriers have been researched for their possible application in eye surgery to repair detached retinas.[23]

Delivery of drugs:

The idea of "magnetic drug delivery" was once mentioned as a particularly promising usage for magnetic nanoparticles about 40 years ago. The process of magnetic targeted treatment begins with the attachment of drug molecules to magnetic nanomaterials, followed by the injection and guidance of these particles to a site of action under the influence of localized magnetic field-gradients, and retention at site until the end of therapy and closing removal. Six different kinds of magnetic materials—diamagnetic, paramagnetic, ferromagnetic, superparamagnetic, ferromagnetic, and antiferromagnetic are described in literature.[24]

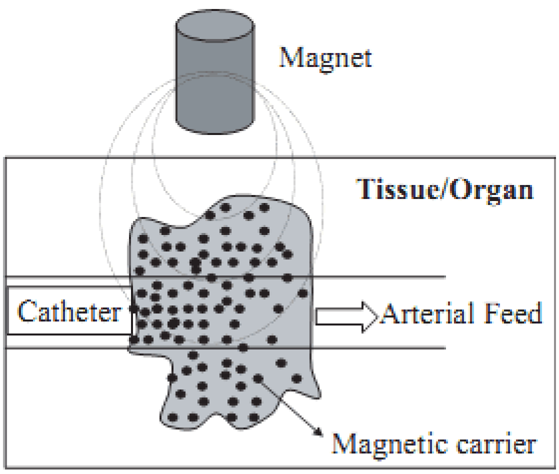

Figure 2: Schematic representation of the magnetically driven transport of drugs to a specific region[25]

Superparamagnetic materials become non-magnetic when the external field is removed, while paramagnetic materials lose their magnetic momentum. However, if an exterior field is applied, these materials get a suggestive magnetic momentum. Massive drug dosages might be carried by magnetic nanoparticles to achieve excessive local concentration, preventing toxic effects and other undesirable side effects from emerging as a result of excessive drug doses in various organ systems. Authentic clinical trials are difficult to conduct because of size control, stability, biocompatibility, coating-layer for drug binding, and several physiological characteristics, according to in vivo research.

A rather active area of research is the use of therapeutic proteins, nucleic acids, and cells to cure a variety of preconditions; these biotherapeutics are beautiful potential remedies because of their innate specificity. Unfortunately, poor delivery mechanisms typically limit the effectiveness of biotherapeutics.[26,27]

Nucleic acid and protein delivery:

Treatments based on nucleic acids and proteins are typically designed to maximize cell absorption. Nonviral vectors, like the usage of MNPs as vectors, are unexpectedly in demand given the worries about viral safety and expensive manufacturing techniques. Here, external magnetic fields are employed to manipulate SPNs into merchandising the accumulation and deposition of nucleic acid-based treatment options frequently leading to the expression or suppression of a gene. For instance, by functionalizing MNPs with synthetic silencing RNA (siRNA) molecules through ionic interactions, researchers have validated noticeably reduced gene expression rates in vitro. The Type 1 insulin-like increase component receptor was the target of conjugated Polyethyleneimine-coated MNPs and lipofectamines containing plasmid DNA producing short-hairpin RNA (IGF-1R). They used magnetoception in vivo to measure the gene suppression charge after a 72-hour incubation period and found that it was approximately 2-fold higher.[27]

Table 2: Physical and chemical properties of compounds mainly used to produce Magnetic nanoparticle.[28]

Material	**Chemical symbol**	**Magnetism**	**Curie temperature (K)**	**DC (nm)**
Iron	Fe	Ferromagnetic	1043	~15
γ-Iron (III) oxide	γ-Fe2O3	Superparamagnetic	948	<100
Strontium ferrite	SrFe12O19	Superparamagnetic	~450	<100
Nickel	Ni	Ferromagnetic	627	55
Chromium (IV) oxide	CrO2	Ferromagnetic	~390	<100
Europium oxide	EuO	Paramagnetic	69	<100

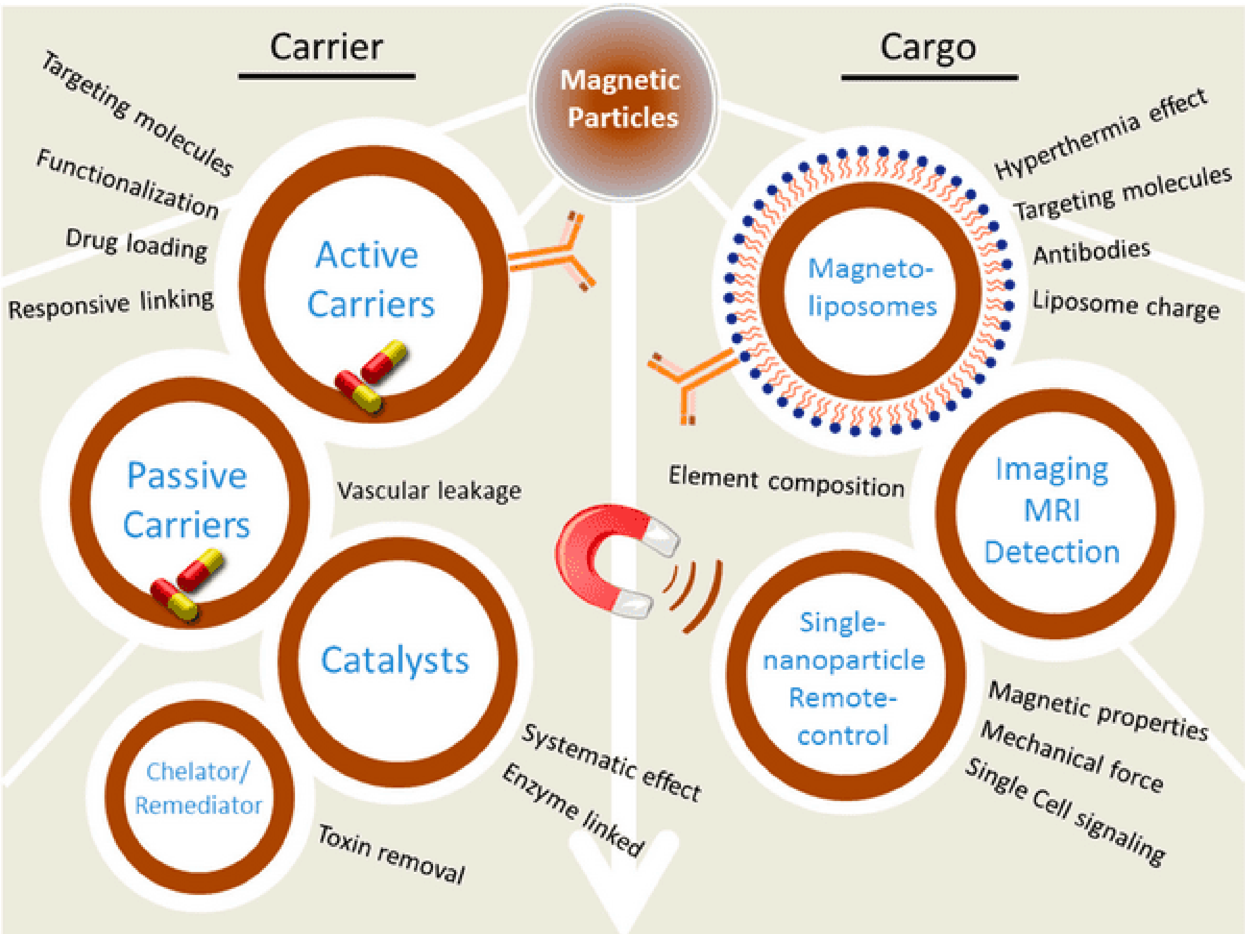

Figure 3. The scheme of magnetic particles utilization.[29]

Design of Magnetic Nanoparticles:

It is no longer easy to implement the concept of employing magnetic nanoparticles for nanomedicine applications. A wide range of factors must be considered at every stage of the synthesis. Although they can be adjusted during the original design stages, these elements have the potential to drastically alter the projected output. The physical and chemical properties of particles can be changed to suit a variety of applications. In nanomedicine, and more specifically in the field of treating the majority of cancers, magnetic nanoparticles are frequently used. Magnetic nanoparticle devices or magnetic composites are excellent for delivering medications because they may respond to external magnetic field stimuli. This enables control over the dosage, timing, and site of drug delivery. Through the use of certain ligands or passively via the leaky vascular environment, nanocarriers can interact with the tumor environment. Magnetic nanoparticles were used as a drug delivery mechanism when doxorubicin, an anthracycline antibiotic with anticancer activity, was combined to apoferritin for targeted most cancers therapy. Targeted magnetic particle MRI was been used to regulate doxorubicin delivery.[30]

Physical Design:

The measurement of magnetic nanoparticles is an important primary physical attribute that should be used to design various properties, such as magnetism and surface area. The regulated specific size synthesis of iron oxide nanoparticles has been explained by a number of researchers. For instance, organic-phase synthesis has been used to produce particles with a diameter of less than 20 nanometers. [31,32] A subsequent size extend was first controlled by a seed-mediated growth. The fundamental variables affecting particle size in the first phase are reaction time and the boiling point of the solvent. The particles are covered by the researchers to provide a stable system. The attraction between different particles is maintained in part by the surface charge. Maximize the number of inert to highly reactive compounds on the surface to ensure the colloidal balance of the nanoparticles.[33]

Magnetic properties are essential for nanoparticles employed in externally controlled hyperthermia or heating activated with the help of generated magnetic fields. The magnetic pressure has the ability to move and transport biological objects. It has been demonstrated that the capacity to apply a mechanical force inside of cells is favorable for molecular stage cell-signaling and altering cell fate. These abilities have been used to remotely control single cell processes, distribute drugs, and treat ailments.

Metallic iron and cobalt-fabricated magnetic nanoparticles provide higher magnetization, but the former needs a coating to stop oxidation. Platinum-based magnetic nanoparticles show extraordinary promise as contrast agents for MRI and X-ray computed tomography (CT). On the other hand, porous magnetic nanoparticles have the same characteristics as strong nanoparticles but have a greater capacity for drug retention and release. Chemical Design: There are essentially two ways stated when it comes to magnetic particle functionalization. While in the second, inorganic materials are coupled with other nanocomponents, such as quantum dots, antibodies and oligonucleotides, which are biomaterials, are modified in the first. To obtain a homogeneous dispersion of nanoparticles and a closely controlled temperature range in tumour tissue, methods like magnetic particle hyperthermia are used.[34]

Magneto liposomes, especially those combined with antibodies, can transfer magnetic nanoparticles inside tumour cells. presented a contemporary viewpoint on the chemistry of magnetic particles' production for drug delivery. They provided a clear explanation of the surface changes that can be covalent and non-covalent. Magnetic nanoparticles are advantageously covalently linked with medications to prevent cancer therapy resistance and therapeutic adverse effects. The covalent bonds need to be reactive in the biological environment, which can happen when pH or temperature change or, obviously, when enzymes can cleave them. Non-covalent drug conjugation to nanoparticles has been employed by researchers. One effective approach of drug administration was the conjugation of pharmaceuticals to magnetic nanoparticles via hydrophobic interaction, electrostatic contact, and coordination chemistry.[35,36]

Applications:[37–39]

Application in industry

Magnetic iron oxides are mostly used as a synthetic colorant in porcelain, paints, and ceramics. Magnetic encapsulates could be very valuable in a wide range of industrial fields as well as in many aspects of daily life. These substances are intriguing from the standpoint of both their potential uses and critical materials science expertise. Hematite and magnetite have been utilized as catalysts for numerous important reactions, including the production of NH3, the desulfurization of medical gas, and the high-temperature water-gas shift reaction. Other processes include the dehydrogenation of ethylbenzene to styrene, the oxidation of alcohols, the Fishere-Tropsch synthesis of hydrocarbons, the scalable synthesis of butadiene, and the dehydrogenation of benzene to styrene.[40]

Biological medicine applications

There are two types of magnetic nanoparticle applications in biomedicine: those that are exterior to the body and those that are inside to the body (in vivo, in vitro). The commonly used in diagnostic separation, selection, and magneto relaxometry for in vitro applications should be separated similarly to how it should be in therapeutic (hyperthermia and drug-targeting) and diagnostic applications for in vivo applications (nuclear magnetic resonance imaging).[41]

In-vivo applications

Two crucial elements that are crucial for these particles' in vivo usage are size and surface functioning. The in vivo biodistribution is significantly influenced by the diameters of superparamagnetic iron oxide NP, which are concentrated on the ligand surface. For prolonged blood circulation, ultra-small SPIOs and particles with sizes between 10 and 40 nm are required; they can pass through capillary walls and are regularly phagocytosed by macrophages that go to the lymph nodes and bone marrow.[42]

Application in therapy

The magnetization direction of superparamagnetic iron oxide randomly switches between parallel and antiparallel orientations when exposed to variable current [AC] magnetic fields, causing hyperthermia. This feature can be employed in vivo to increase the temperature of tumour tissues so that hyperthermia can kill the diseased cells. Tumor cells are more sensitive to temperature changes than healthy ones are. Dextran-coated magnetite and magnetite cationic liposomal nanoparticles have previously demonstrated the ability to successfully increase tumour cell temperatures in order to treat them with hyperthermia during cell radiotherapy. This has been proposed as one of the key tactics for effective cancer treatment in the future.[43,44]

Selection and separation; diagnostic applications. To extract and concentrate desired compounds from samples, solid-phase extraction is now widely used. Trace-level contaminants can be recovered from environmental samples using SPE. The recent quick and large increase of nanoparticles, also known as NPs, has had a profound impact on pattern extraction. SPE provides an excellent alternative to traditional sample concentration methods like liquid-liquid extraction. The preconcentration and separation of the material from enormous volumes of solution can be quite time-consuming when employing the traditional column SPE. The use of magnetic or magnetizable adsorbents, often known as magnetic solid-phase extraction (MSPE), is relevant in this sector. In this method, the target and magnetic adsorbent are both added to a solution or suspension.[45]

Bioseparation.

In biomedical research, it is commonly required to examine separate biological entities (such as DNA, proteins, and cells) isolated from their natural settings. [46,47] Superparamagnetic colloids are perfect for this usage because of their on-off magnetization with and without an external magnetic field, which allows the transportation of biomaterials with a magnetic field. In a conventional separation method, the biological components are marked with superparamagnetic colloids and then transferred to separation using an external magnetic field. Excellent paramagnetic iron oxide particles are a class of tiny magnetic particles that are frequently used in bioprocesses to sort and purify cells and biomolecules.[48]

Catalysis applications:

Until now, the use of catalysts assisted by MNPs has greatly reduced the heterogeneous catalysis's limitation. The restoration of catalysts in a liquid-phase reaction is far less challenging when magnetically driven separations are used rather than moving go with the flow filtration and centrifugation, especially when the catalysts are in the sub-micrometer size range. Such minuscule, magnetically separable catalysts ought to benefit from both high reactivity and dispersion as well as separation simplicity. The facile separation of catalysts in a quasihomogeneous environment made possible by the immobilization of these active species on MNPs is advantageous for the reuse of expensive catalysts or ligands. Among the many transition metal-catalyzed reactions that have lately emerged and made use of the catalytic sites included into magnetic nanoparticles are carbon-carbon and cross-coupling reactions, as well as polymerization processes. both hydroformylation and hydrogenation.[49]

Analytical applications:

fluorescent techniques. Magnetic luminous NPs have a higher surface area-to-volume ratio than often utilised microbeads, which promotes a more homogenous reaction and quicker reaction kinetics. Some of the easier methods to create magnetic fluorescent nanoparticles include coating iron oxide particles with dye-doped silica shells, [50,51] embedding iron oxide and quantum dots inside silica NPs, and entrapping natural dyes or quantum dots inside polystyrene magnetic beads. They are frequently only used for biological purposes like cell imaging. Only a few studies have discussed the use of dual functional NPs for multiplexed quantitative bioanalysis.[52]

Inorganic and hybrid coatings (or shells) have been produced on colloidal templates utilizing precipitation and surface reactions. By carefully selecting the experimental parameters, which are frequently the kind of precursors, temperature, and ph, this process can generate uniform, straightforward coatings and ultimately result in monodispersed spherical composites.[53]

CONCLUSION:

Due to their unique capabilities to circumvent some of the challenges associated with effectively targeting a wide range of cell types, magnetic nanoparticles hold great potential for drug delivery architectures. The future is promising, but it also calls for challenging and original research ideas to be developed in order to expand its potential for the treatment of other ailments. Iron oxide magnetic nanoparticles have exceptional potential in medicinal applications and a strong case for aqueous/nonaqueous segment solubility. The right precursors, the pH of the medium, coating suppliers, and solvents for the synthesis of magnetic nanoparticles all play important roles in obtaining this. The application of water-soluble surface functionalization dealers via thermal degradation, co-precipitation, microwave, and high-temperature techniques can significantly increase aqueous phase solubility.

We need to be aware of the synthesis and coating processes in order to represent and control the physicochemical properties of MNPs. Different MNP structure models have each been claimed to offer benefits. The creation and use of increasingly sophisticated applied sciences are of utmost importance in the synthesis of novel MNPs and in the study of their activity in the body. Finally, new insights into the function of magnetic nanoparticles in improving nanocarriers that enable increasing the effectiveness of contemporary theranostics are revealed by the scientific data gathered here while assembling this assessment.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interests.

ACKNOWLEDGEMENTS

I would like to thank [Name of Guide] for her help and assistance in writing this manuscript. I would also like to thank [Name of Principal]. Principal of [Name of college] his support on the manuscript.

REFERENCES:

1. Materón EM, Miyazaki CM, Carr O, Joshi N, Picciani PHS, Dalmaschio CJ, et al. Magnetic nanoparticles in biomedical applications: A review. Applied Surface Science Advances. 2021 Dec 1;6.
2. Akbarzadeh A, Samiei M, Davaran S. Magnetic nanoparticles: Preparation, physical properties, and applications in biomedicine. Nanoscale Res Lett. 2012;7.
3. Sreenivasulu K, Satyaveni M, Rajwardanreddy M, Sai Sowjanya M, Nama S, Baburao C. A REVIEW ON MAGNETIC NANO PARTICLES [Internet]. Vol. 3. 2013. Available from: www.ijcpcr.com
4. Gul S, Khan SB, Rehman IU, Khan MA, Khan MI. A Comprehensive Review of Magnetic Nanomaterials Modern Day Theranostics. Vol. 6, Frontiers in Materials. Frontiers Media S.A.; 2019.
5. Akbarzadeh A, Samiei M, Davaran S. Magnetic nanoparticles: Preparation, physical properties, and applications in biomedicine. Nanoscale Res Lett. 2012;7.
6. Materón EM, Miyazaki CM, Carr O, Joshi N, Picciani PHS, Dalmaschio CJ, et al. Magnetic nanoparticles in biomedical applications: A review. Applied Surface Science Advances. 2021 Dec 1;6.
7. Wu K, Su D, Liu J, Saha R, Wang JP. Magnetic nanoparticles in nanomedicine: a review of recent advances. Nanotechnology [Internet]. 2019 Sep 27 [cited 2023 Jan 14];30(50). Available from: https://pubmed.ncbi.nlm.nih.gov/31491782/
8. Singh D, Mcmillan JEM, Kabanov A v., Sokolsky-Papkov M, Gendelman HE. Bench-to-bedside translation of magnetic nanoparticles. Nanomedicine. 2014;9(4):501–16.
9. Shaukat A, Hussain G, Irfan S, Ijaz MU, Anwar H. Therapeutic Potential of MgO and MnO Nanoparticles Within the Context of Thyroid Profile and Pancreatic Histology in a Diabetic Rat Model. Dose-Response. 2022 Jul 1;20(3).
10. Wu K, Liu J, Chugh VK, Liang S, Saha R, Krishna VD, et al. Magnetic nanoparticles and magnetic particle spectroscopy-based bioassays: a 15 year recap. Nano Futures [Internet]. 2022 Jun 1 [cited 2023 Jan 14];6(2). Available from: http://www.ncbi.nlm.nih.gov/pubmed/36199556
11. Nikitin AA, Ivanova A v., Semkina AS, Lazareva PA, Abakumov MA. Magneto-Mechanical Approach in Biomedicine: Benefits, Challenges, and Future Perspectives. Int J Mol Sci. 2022 Oct 1;23(19).
12. Unsoy G, Gunduz U, Oprea O, Ficai D, Sonmez M, Radulescu M, et al. Magnetite: From Synthesis to Applications. Curr Top Med Chem. 2015 Apr 18;15(16):1622–40.
13. Vallabani NVS, Singh S, Karakoti AS. Magnetic Nanoparticles: Current Trends and Future Aspects in Diagnostics and Nanomedicine. Curr Drug Metab. 2018 Nov 29;20(6):457–72.
14. Zimina TM, Sitkov NO, Gareev KG, Fedorov V, Grouzdev D, Koziaeva V, et al. Biosensors and Drug Delivery in Oncotheranostics Using Inorganic Synthetic and Biogenic Magnetic Nanoparticles. Biosensors (Basel). 2022 Oct 1;12(10).
15. Mosayebi J, Kiyasatfar M, Laurent S. Synthesis, functionalization, and design of magnetic nanoparticles for theranostic applications. Adv Healthc Mater. 2017 Dec 6;6(23).
16. Namiot ED, Sokolov A v., Chubarev VN, Tarasov V v., Schiöth HB. Nanoparticles in Clinical Trials: Analysis of Clinical Trials, FDA Approvals and Use for COVID-19 Vaccines. Int J Mol Sci. 2023 Jan 1;24(1).
17. Li X, Wei J, Aifantis KE, Fan Y, Feng Q, Cui FZ, et al. Current investigations into magnetic nanoparticles for biomedical applications. J Biomed Mater Res A. 2016 May 1;104(5):1285–96.
18. Farinha P, Coelho JMP, Reis CP, Gaspar MM. A comprehensive updated review on magnetic nanoparticles in diagnostics. Nanomaterials [Internet]. 2021 Dec 1 [cited 2023 Jan 14];11(12). Available from: /pmc/articles/PMC8706278/

19. Flores-Rojas GG, López-Saucedo F, Vera-Graziano R, Mendizabal E, Bucio E. Magnetic Nanoparticles for Medical Applications: Updated Review. Macromol 2022, Vol 2, Pages 374-390 [Internet]. 2022 Aug 2 [cited 2023 Jan 14];2(3):374–90. Available from: https://www.mdpi.com/2673-6209/2/3/24/htm
20. le Renard PE, Jordan O, Faes A, Petri-Fink A, Hofmann H, Rüfenacht D, et al. The in vivo performance of magnetic particle-loaded injectable, in situ gelling, carriers for the delivery of local hyperthermia. Biomaterials. 2010;31(4):691–705.
21. Peng XH, Qian X, Mao H, Wang AY, Chen ZG, Nie S, et al. Targeted magnetic iron oxide nanoparticles for tumor imaging and therapy. Int J Nanomedicine. 2008;3(3):311–21.
22. Rosensweig RE. Heating magnetic fluid with alternating magnetic field. J Magn Magn Mater. 2002 Nov;252(1-3 SPEC. ISS.):370–4.
23. Laurent S, Forge D, Port M, Roch A, Robic C, vander Elst L, et al. Magnetic iron oxide nanoparticles: Synthesis, stabilization, vectorization, physicochemical characterizations and biological applications. Chem Rev. 2008 Jun;108(6):2064–110.
24. Wang X, Qin J, Zhang Y, Ma J. Stimuli-responsive self-regulating magnetic-thermal materials for selective magnetic hyperthermia therapy. OpenNano. 2022 Jul 1;7.
25. Ito A, Shinkai M, Honda H, Kobayashi T. Medical application of functionalized magnetic nanoparticles. J Biosci Bioeng. 2005;100(1):1–11.
26. Pankhurst QA, Thanh NKT, Jones SK, Dobson J. Progress in applications of magnetic nanoparticles in biomedicine. J Phys D Appl Phys. 2009;42(22).
27. Safari A, Sarikhani A, Shahbazi-Gahrouei D, Alamzadeh Z, Beik J, Dezfuli AS, et al. Optimal scheduling of the nanoparticle-mediated cancer photo-thermo-radiotherapy. Photodiagnosis Photodyn Ther. 2020 Dec 1;32.
28. Nandhini G, Shobana MK. Role of ferrite nanoparticles in hyperthermia applications. J Magn Magn Mater. 2022 Jun 15;552.
29. Yoshida Y, Fukui S, Fujimoto S, Mishima F, Takeda S, Izumi Y, et al. Ex vivo investigation of magnetically targeted drug delivery system. J Magn Magn Mater. 2007 Mar;310(2 SUPPL. PART 3):2880–2.
30. Owen J, Rademeyer P, Chung D, Cheng Q, Holroyd D, Coussios C, et al. Magnetic targeting of microbubbles against physiologically relevant flow conditions. Interface Focus. 2015 Oct 6;5(5):1–12.
31. Anik MI, Hossain MK, Hossain I, Mahfuz AMUB, Rahman MT, Ahmed I. Recent progress of magnetic nanoparticles in biomedical applications: A review. Nano Select [Internet]. 2021 Jun 1 [cited 2023 Jan 14];2(6):1146–86. Available from: https://onlinelibrary.wiley.com/doi/full/10.1002/nano.202000162
32. Wu B, Shang H, Liang X, Sun Y, Jing H, Han X, et al. Preparation of novel targeting nanobubbles conjugated with small interfering RNA for concurrent molecular imaging and gene therapy in vivo. FASEB Journal. 2019 Dec 1;33(12):14129–36.
33. Mosayebi J, Kiyasatfar M, Laurent S. Synthesis, functionalization, and design of magnetic nanoparticles for theranostic applications. Adv Healthc Mater. 2017 Dec 6;6(23).
34. Öztürk Er E, Dalgıç Bozyiğit G, Büyükpınar Ç, Bakırdere S. Magnetic Nanoparticles Based Solid Phase Extraction Methods for the Determination of Trace Elements. Crit Rev Anal Chem. 2022;52(2):231–49.
35. Chang D, Lim M, Goos JACM, Qiao R, Ng YY, Mansfeld FM, et al. Biologically targeted magnetic hyperthermia: Potential and limitations. Front Pharmacol. 2018 Aug 2;9(AUG).
36. Li J, Feng Z, Gu N, Yang F. Superparamagnetic iron oxide nanoparticles assembled magnetic nanobubbles and their application for neural stem cells labeling. J Mater Sci Technol. 2021 Feb 10;63:124–32.
37. Caster JM, Patel AN, Zhang T, Wang A. Investigational nanomedicines in 2016: a review of nanotherapeutics currently undergoing clinical trials. Wiley Interdiscip Rev Nanomed Nanobiotechnol. 2017 Jan 1;9(1).
38. Rui H, Xing R, Xu Z, Hou Y, Goo S, Sun S. Synthesis, functionalization, and biomedical applications of multifunctional magnetic nanoparticles. Advanced Materials. 2010 Jul 6;22(25):2729–42.
39. Yu J, Ju Y, Chen F, Che S, Zhao L, Sheng F, et al. Chemical Synthesis and Biomedical Applications of Iron Oxide Nanoparticles. Nanobiomaterials. 2017 Dec 1;329–58.
40. Wang X, Ramalingam M, Kong X, Zhao L, editors. Nanobiomaterials. 2018 Jan 9 [cited 2023 Jan 14]; Available from: http://doi.wiley.com/10.1002/9783527698646
41. Xu C, Sun S. Monodisperse magnetic nanoparticles for biomedical applications. Polym Int. 2007 Jul;56(7):821–6.

42. Cardoso VF, Francesko A, Ribeiro C, Bañobre-López M, Martins P, Lanceros-Mendez S. Advances in Magnetic Nanoparticles for Biomedical Applications. Adv Healthc Mater. 2018 Mar 7;7(5).
43. Lu AH, Salabas EL, Schüth F. Magnetic nanoparticles: Synthesis, protection, functionalization, and application. Angewandte Chemie - International Edition. 2007;46(8):1222–44.
44. Sun B, Long YZ, Zhang HD, Li MM, Duvail JL, Jiang XY, et al. Advances in three-dimensional nanofibrous macrostructures via electrospinning. Prog Polym Sci. 2014;39(5):862–90.
45. Wang Q, Geng Y, Li J, Yin M, Hu Y, Liu Y, et al. Novel magnetic-fluorescent bifunctional Janus nanofiber membrane. Nanotechnology. 2018 Feb 12;29(13).
46. Zhou X, Ma Q, Yu W, Wang T, Dong X, Wang J, et al. Magnetism and white-light-emission bifunctionality simultaneously assembled into flexible Janus nanofiber via electrospinning. J Mater Sci. 2015 Dec 30;50(24):7884–95.
47. Wang S, Liu Q, Zhang Y, Wang S, Li Y, Yang Q, et al. Preparation of a multifunctional material with superhydrophobicity, superparamagnetism, mechanical stability and acids-bases resistance by electrospinning. Appl Surf Sci. 2013 Aug 15;279:150–8.
48. Mohammadkhani F, Montazer M, Latifi M. Microwave absorption characterization and wettability of magnetic nano iron oxide/recycled PET nanofibers web. Journal of the Textile Institute. 2019 Jul 3;110(7):989–99.
49. Murillo-Ortíz R, Mirabal-García M, Cruz-Rivera JJ, Valdez-Pérez D, Martínez JR, Pérez-Moreno F, et al. Properties and arsenic removal evaluation of polyvinyl alcohol nanofibers with embedded strontium hexaferrite nanoparticles. Mater Chem Phys. 2019 May 15;234:151–7.
50. Mei L, Chen H, Shao Y, Wang J, Liu Y. Highly aligned magnetic composite nanofibers fabricated by magnetic-field-assisted electrospinning PAN/FeCo solution. High Perform Polym. 2019 Mar 1;31(2):230–7.
51. Huang C, Soenen SJ, Rejman J, Trekker J, Chengxun L, Lagae L, et al. Magnetic electrospun fibers for cancer therapy. Adv Funct Mater. 2012 Jun 20;22(12):2479–86.
52. Sung YK, Ahn BW, Kang TJ. Magnetic nanofibers with core (Fe 3O 4 nanoparticle suspension)/sheath (poly ethylene terephthalate) structure fabricated by coaxial electrospinning. J Magn Magn Mater. 2012 Mar;324(6):916–22.
53. Ahn BW, Kang TJ. Preparation and characterization of magnetic nanofibers with iron oxide nanoparticles and poly(ethylene terephthalate). J Appl Polym Sci. 2012 Jul 15;125(2):1567–75.