Journal of New Materials for Electrochemical Systems
Vol. 25, No.1, January 2022, pp. 07-16
Journal homepage: http://iieta.org/journals/jnmes

Synthesis and applications of biopolymer /FeO nanocomposites: A review

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ABSTRACT

Magnetic oxide nanoparticles have engaged most consideration due to their rare character, such as easy separation, surface-to-volume ratio, paramagnetic and high surface area. Natural biopolymers, namely, (Chitosan, Guar-Gum, Tamarind, Alginate, Dextran, Pectin) have posed as an incredible host for the preparation of magnetic nanoparticles. Biopolymer based magnetic nanocomposites have been fabricated from long time using method like co-precipitations, green synthesis, in-situ, hydrothermal and wet chemical method. Properties of biopolymer magnetic nanocomposites draw attention to the researchers towards fabricating at the nano level for various applications like as adsorptions inorganic metal, organic impurity, targeted drug-delivery, bio-sensing, catalysis activity, antimicrobial activity, antifungal activity, antioxidant activity, anti-cancer activity, energy, environmental remediation, waste water treatment and textiles. This review is designed to report very firstly reported biopolymer magnetic nanoparticles (BMNPs) in last ten years and attractive approach in various applications.

Keywords: *Biopolymers; Biopolymer magnetic nanoparticles; Adsorptions, Antimicrobial activity, Antioxidant, Catalyst activity*

Received: September-2021 **Accepted**: November 29-2021 https://doi.org/10.14447/jnmes.v25i1.a02

1. INTRODUCTION

Implications and applications of nanomaterials have been widely explored. The improvement of nanotechnology has implement assets to numerous utilizations in the medical field, leading to important advances in terms of adsorptions, biological detection, diagnosis, , and drug delivery [1] The nanomaterials stand out as indispensable and superior in several fields, owing to their exclusive size-dependent properties.[2]

Generally, magnetic oxides are frequent, widely used as they are reasonable and play an essential role in various geological and biological processes. They are also predominantly usage by humans, for example, ores in catalysts, thermite , magnetic , durable pigments (colour concrete and coatings, paints,) and haemoglobin [3] Magnetic nanoparticles have been adsorbents catalysts, sensors, reducing agents and bactericides such as superparamagnetic iron oxide nanoparticles [4] The potential applications of magnetic nanoparticles in the bio-medical field, like as magnetic resonance imaging and magnetic separation, [5] targeted drug delivery, hyperthermia treatment for cancer, antibacterial activity and biomedical[6-8] have been of great interest, lately. They exhibit quick kinetics and appreciate adsorption capacity because of their high surface to volume ratio [9]. The metallic nanoparticles (MNPs) are especially attractive due to their exclusive properties and differing applications [10]. It has been approved that the dispersibility, morphology, size, , and physio-chemical character of MNPs are vigorously coordinate with their applications, which are afflicted by the synthetic access [11]. Biopolymers are naturally environmentally eco-friendly, abounding and, inexpensive polymers. Opportunity are extensively used in agricultural, industries, medical, and environmental because of their especially sustainable, renewable, and non-toxic characteristics [12]. This has also been reflected in the metal-polymer nanocomposites research area biopolymers, such as (chitosan, starch, alginate, tamarind gum, pectin. Cellulose, Gelatine, Guar gum, dextran, Mannan, PAA, PVA-A, Pectin etc.) [13-25]

Figure 1 shows magnetic nanoparticles' various properties as sorbents, reducing /oxidizing agents, nano-magnets, etc. The second step helps illustrates how individual imperfections of nanoparticles and bio polymeric host materials are abolished by using nanocomposites.

Biopolymer Magnetic Nanoparticles have been synthesized using different methods such as Green synthesis[12] electrodeposition [26] Combustion[27] in situ[28] ex-situ [29] wet method[81] (hydrothermal[46] co-precipitation [30] Incorporation of natural biopolymer into magnetic nanoparticles increases its application on a massive scale like Biomedical [101], Adsorption[31] Environmental[32] (Liang Drug delivery[33] Antimicrobial activity [34] Antioxidant activity[35] Anti-cancer activity[36] and catalyst activity [37].

The prime focus of the present article is the synthesis of biopolymer based magnetic metal nanoparticles/ nanocomposites and their applications. The review shall more over its readers with a knowledge of recent methods that are being employed for the synthesis of BMNPs and their biomedical applications.

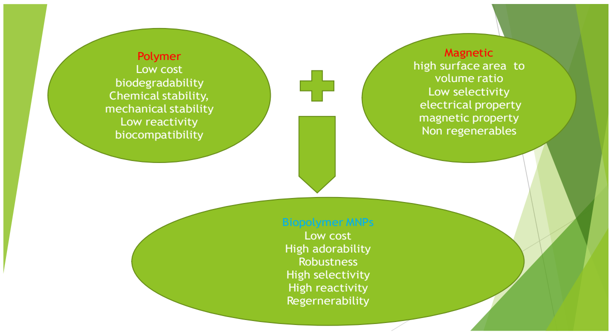

Figure 1. Distinct properties of magnetic nanoparticles usage for various environmental applications and characteristics of biopolymer-based nanoparticles

2. SYNTHESIS OF BIOPOLYMER MAGNETIC NANOPARTICLES (BMNPS).

Biopolymers: Researcher has been performed to appropriate biocompatible, non-toxic synthetic materials for the synthesis and stabilization of magnetic nanoparticles biopolymer composites (Table 1).

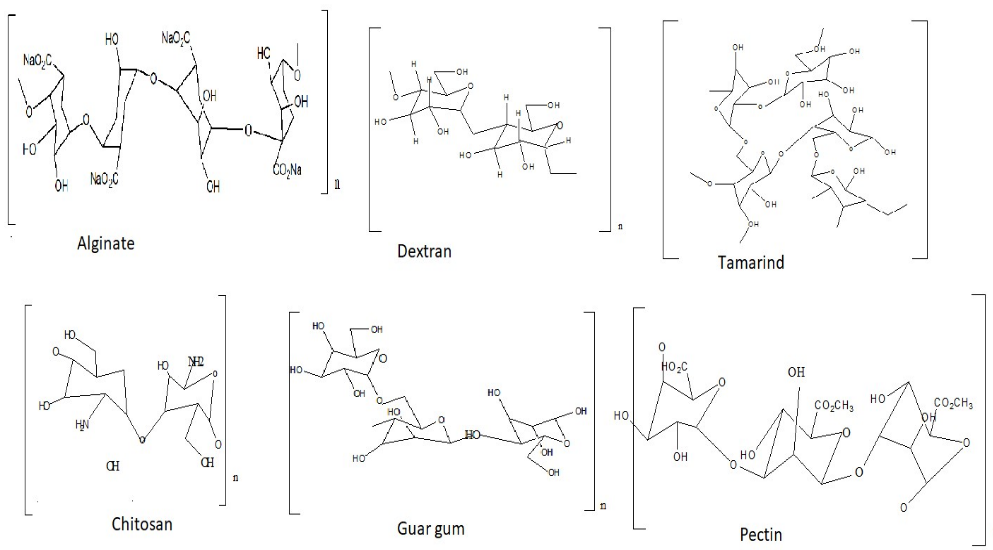

Figure 2. Frequently used Biopolymer chemical structure; Chitosan, Tamarind, Dextran, Guar gum, Alginate, Gelatin, and Pectin.

Table 1. Literature data regarding synthesis of BMNPs

Biopolymer	Magnetic/Magnetic oxide	Method	Size	Shape	Reference
Agarose/dextran/gelatin	Fe_2O_3	Green synthesis	10nm	Dumbbell	[10]
Alginate	Fe (III)/Ni (II)	Ex-situ			[29]
Alginate	Fe (II)	Ex situ	35nm	Spherical	[8]
Sodium alginate	Fe_3O_4	Hydrothermal	27.2 nm	Spherical	[38]
β-cyclo-dextrin/ chitosan	Fe	Green synthesis	25-65nm	-	[36]
Chitosan	Fe	Co-precipitating		-	[39]
Chitosan	Fe	Co- precipitation	18-26nm	-	[40]
Chitosan	Fe_2O_3	Co precipitations		-	[41]
Chitosan	Fe	In-situ	35-48nm	-	[42]
Chitosan	Fe	Co-precipitation	30 nm	----	[43]
Chitosan	Fe	Wet chemical	6-10nm	---	[44]
Chitosan	Fe	Wet chemical		----	[45]
Chitosan	Fe	Hydrothermal	13.5	Spherical	[46]

Chitosan and alginate	Magnetite	Ex-situ	15-35	Quraish e pical	[47]
Chitosan	Fe_3O_4	Ex-situ		----	[48]
Carboxylate polyacrylamide	Fe_3O_4	Co-precipitations	15- 26		[49]
Guar gum (GG)	(Fe_3O_4)	Co-precipitations	90-95	Spherical	[50]
Nitrocellulose,	Fe2O3 NPs,	Combustion waves	5–20	-	[51]
Styrene	Fe_3O_4	Ex- situ	30-40	Spherical	[52]
Starch-Pectin	Magnetite	Green synthesis		--	[14]
(PMMA)	Fe/Fe-oxide	Ex-situ	6–15		[53]

Magnetic metal nanoparticles incorporated with different biopolymer (Chitosan, Guar-gum, Tamarind, Alginate, Dextran, Pectin) (Table 1.) have been synthesized by various methods for different Sub-spatial development in the shape and size supervision of BMNPs has been made by progressive methods thermal decomposition, co-precipitation, wet chemical method, green synthesis, hydrothermal synthesis, in-situ, ex-situ precipitations and combustions. Herein, we discuss the synthesis of BMNPs of different morphologies using a variety of synthetic routes. Synthesis for biopolymers is interpreted by Fe nanoparticles using Co-precipitations methods [54-55].

2.1 Co-precipitation method

Co-precipitation is a very effective method to acquire magnetic oxide Fe2O3 or Fe_3O_4. Magnetic oxide nanoparticles analysis by this method is often unstable and hence stabilized by average molecular weight surfactants or functionalized biopolymers. The particle shape, size, and composition of the processed iron nanoparticles can be controlled by changing the testing conditions. Important accelerate in preparing monodisperse magnetic nanoparticles with various sizes have been formed using organic additives as stabilization or reducing agents. Other biopolymers like; chitosan, Carboxylate, polyacrylamide, Guar gum (G.G.), Cellulose etc. has been used for stabilization of metallic Fe nanoparticle [40] [51] [55-58]

2.2 In-situ method

The consolidation of the vast number of functionalized biopolymers accessible and various category of nanoparticles that can be formed provide increase to many numerous biopolymers possible to be synthesized. The range that controls the nature of the biopolymers is the functional polymer, precursors, reactions, the reaction that forms the nanoparticles, and the composition of the magnetic oxide nanoparticles. Within process, the biopolymers delivers as nanoreactors and provide a confined intermediate for synthesis; also, they isolate and stabilize the synthesized nanoparticles preclude their gathering. Many syntheses of biopolymers and magnetic nanoparticles stabilized by in situ methods like as the biopolymers use for the chitosan, polyvinyl alcohol (PVA), and crosslinking agent uses to glutaraldehyde stabilize magnetic nanoparticles [59-60].

2.3 Ex-situ method

The ex-situ method accords of physical entanglement of the metal or metal oxides nanoparticles in the biopolymer or polymer organizations. Table encapsulate few of the approach usage for polymerization for ex-situ synthesis of the BMNPs. In addition to the manufacturing polymers, biopolymers such as alginate, chitosan, pectin, cellulose, dextran, tamarind, guar gum etc., have been widely used for ex-situ synthesis of the BMNPs. Various of the biopolymers are soluble in acidified aqueous solution. The preparation of BMNPs containing bio-polymer with entrapped magnetic oxide metal by synthesis of ex-situ method in very cases, biopolymer nanoparticles were conceiving. Amidst solutions having precursor chemicals and dried to produce biopolymers like as the nitrocellulose, chitosan [Styrene-b-ethylene/butylene-b- Chitosan and Alginate stabilized by magnetic nanoparticles [29] [47] [48-52] [61].

2.4 Green synthesis method

The green synthesis technique is an energy-efficient, cost-effective and eco-friendly avenue to synthesize nanoparticles. Biopolymers, algae, plants, bacteria, fungi, and viruses synthesize ZnO N. Ps from this technique. As reported by [62] Synthesis were Magnetic Nanoparticles (Fe_3O_4) were entrapped with β-cyclodextrin (β-CD) @ carboxymethyl (C.S.), (sodium-@alginate)- by green synthesis method. [10] Presented another study wherein they prepared Magnetite Nanoparticles by incorporating a biopolymer using the hydrothermal method. The average nanoparticle size so obtained was documented to be 27.2 nm.[63] reported a wet chemical method. As a result, crystal nuclei with nano dimensions are developed. Upon on the process conditions and materials used, crystals with a variety of shapes and sizes can be accessed [64]

3. APPLICATIONS OF BMNPS

Generally, BMNPs having magnetic oxide N.P.s are developed especially for applications relevant to particular adsorption of target impurity. From the circumstance of other ions, Biopolymers based Fe metal nanoparticles have been considerably used in several technological area changed to their extraordinary biological, chemical, and physical characteristics. BMNPs various areas because the nanoparticles associate the characteristics of the biopolymer and nanoparticles. Illustrations of applications in different criteria include supported metal adsorptions, organic impurity, catalysis activity, sensors and biosensors, biomedical antibacterial activity, antioxidant activity, anti-cancer activity coatings, and other measures. More data has been discussed and summarized in Tables, 2,3, 4 and 5 and broadly shown in Figure 3.

Application of metals removal by BMNPs show in table 2.

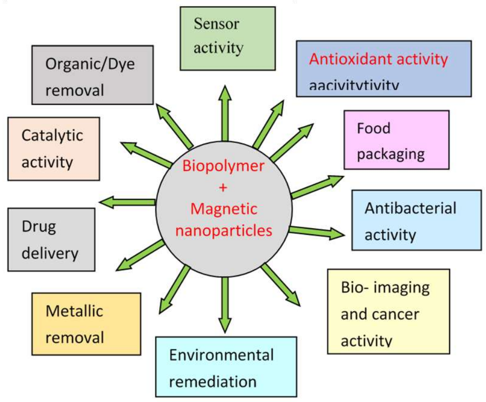

Figure 3. Applications of Biopolymers and based magnetic oxide nanocomposites.

Table 2 Application of metals removal by BMNPs

Biopolymer /Metal	Removal metal	Qmax (mg g−1)	Refe-rences
Alginate /Fe (III) /oxide	As (III), As(V)	85% mg·/g	[65]
Alginate /Fe (III)	As(V)	-	[66]
Alginate /Fe_3O_4	As (III), As(V)	60% mg·/g	[29]
Alginate /Fe_3O_4	Cu (II)	99% mg·/g	[67]
Alginate /Fe_3O_4	Cu2+	-	[68]
Chitosan/ Fe_2O_3	Th (IV)	95% mg·/g	[69]
Chitosan/Fe	Cr	55.80 % mg·/g	[29]
Chitosan /Fe	Cu (II)	-	[70]
Chitosan/Fe	As	-	[29]
CS /Fe_3O_4	Pb (II)		[75]
Chitosan /Fe	Rare-earth metal	30.5% mg/g	[71]
CS NPs / Fe_3O_4/	Heavy metal	79.24 mg/g	[29]
CS / Fe_3O_4	Hg (II)	-	[72]
Starch / Fe_3O_4–	As(V) As(V)	-	[73]
Chitosan / Fe_3O_4–	As (III) As (III)	-	[74]
Chitosan/ Fe_3O_4@SiO 2	Hg^{2+}, Pb^{2+}, Cu^{2+}		[75]

3.1 Applications of BMNPs in metal impurity removal

Assimilated with single polymer adsorbents, metal biopolymer composites exhibition large surface groups, maximum adsorption value, mechanic feasibility and exceptional stability.

Synthesized were calcium alginate hydrous (dropped/coated) ferric beads by adsorptions method beads removal an (As) 85% from aqueous solutions [65] and other studies adsorptions like as the prepared biopolymer nanoparticles Fe (III)@Alginate adsorptions by batch adsorptions method Cu (II)removal by adsorptions batch method,85% removal [29] [66-68]

In any cases, it has been develop that an raising in the ratio of biopolymer and chitosan concentration raising the adsorption of heavy metals [29]. Fe3O4-C18chitosan-DETA (FCCD) particles were used to remove Dy^{3+} Er^{3+} and Nd^{3+}, at 25 ^{0}C and pH 7 of the medium removal by C.S./Fe nanocomposites like as the Hg[72] Another study of starch /Fe_3O4 synthesized using in situ method for the removal As(V). Metal by batch adsorptions method. An, [73] synthesized PMMA /Fe 3 O 4 nanocomposites adoption by Cu2+ , Mn2+ , Zn2+Heavy metal [77] P.B., Adsorption of rare-earth metal ions [71]Remove Arsenic and Its Separation from Water[29] Adsorption of thorium (IV) ion from aqueous solution [69] application for Cu(II) removal [70]

3.2 Applications of BMNPs in organic impurity removal

Show in table 3. associated with single polymer adsorbents, metal biopolymer composites exhibittion very abundant surface groups, high adsorption capacity, mechanic feasibility and better stability.

Table 3. Applications of organic impurity removal by BMNPs

Biopolymer /Magnetic	Organic impurity	References
Fe_3O_4/PAA	Basic dye	[78]
Chitosan /magnetic	Phenol	[79]
Chitosan / Fe_3O_4	Cresol	[39]
Chitosan / Fe	Methylene blue	[40]
Alginate/ Fe	Dye	[80]
Chitosan / Fe	Basic dye	[81]
Chitosan / Fe	Humic acid	[82]
Chitosan / Fe	Methylene blue	[83]
Chitosan / Fe	Clove oil	[84]
Guar gum/coated iron oxide	Congo red dye	[85]
Fe_3O_4–alginate, H_2O_2	3 methyl-indole	[86]
Fe_3O_4/chitosan	BB	[87]
γ-Fe_2O_3/chitosan	Azo dye	[88]

The maximum adsorption capacity was analysed by varying the initial pH and adsorbent dosage and the maximum adsorption capacity like the Adsorptions humic acid [82]

Methylene blue etc. [40][87]. In others, studies synthesized biopolymers Fe_3O_4@PAA nanocomposites and adsorptions by the bath methods for the removal by basic dye [78]. Prepared were Functionalized Guar gum (G.G.) @ iron oxide (Fe_3O_4) nanoparticles by co-precipitation method. The adsorption of different dyes such Rhodamine B, methylene blue Congo red (C.R.), malachite green, Eriochrome Black T, methyl orange and methyl blue. C.R. dye shows maximum adsorption of 97%. nanoparticle spherical shape and size 90-95 nm [83]

Synthesized were magnetic @γ-Fe_2O_3/crosslinked (NPS) by microemulsion process. (NPS) adsorption capacity qe, call (20.12 mg g−1) [88] The developed for magnetic nanoparticles, attached of chitosan-coated co-precipitations method, to be utilized by enzyme immobilization. And the crosslinking agent of glutaraldehyde. For supporting synthesis by the green process, Magnetic nanoparticles (Fe3 O 4) were entrapped with β-cyclodextrin (β-CD) and carboxymethyl chitosan (C.S.) as carriers. Nanoparticles size 25-65nm spherical and its applications of anti-cancer activity [95] synthesis of iron oxide magnetic @polyacrylic acid-bound nanoparticles by co-precipitations method. The Fe_3O_4@PAA (NPS) were used to adsorb Rhoda-mine 6G (R6G). the essential dye pollutant from an aqueous solution. Adsorption and isotherms kinetics data were better fitted by Langmuir isotherm and pseudo-second-order kinetic model, respectively. The adsorption equilibrium about 20 min delivered [78] magnetite (Fe_3O_4) @ PAM/oleic acid/nanocomposites. Phosphate is one of the primary pollutants responsible for the eutrophication of adsorption is a potential treatment and surface waters process for this pollutant. A magnetic adsorbent assembled from the phosphate adsorption good behaviour by both with the Freundlich and Langmuir maximum adsorption quantity (*Q.E.*), gibbs free energy and adsorption isotherm of the phosphate was 28.95 mg/goat 298 K and −12.89 kJ/mol, respectively. The derived activation energy and adsorption kinetics, 28.29 kJ/mol, could best describe a pseudo-second-order model. [102] Synthesized were iron (II) magnetic @alginate beads nanoparticles by co-precipitation method. The objective of using them in the advanced Fenton oxidation of malodorous materials (3 methyl-indole: 3-MI). The objective revealed that the parameters affecting Fenton catalysis must be carefully chosen to avoid excessive iron clemency. Total adsorptions of 3 methyl indole and remarkable organic mineralization, without character leaching of magnate, were attained within 120 min,9.8 m mol L−1 at pH 3.0 by using 0.4 g L−1 of Fe-MABs of H_2O_2 .The novel magnetic catalyst would be of application due to the efficiency of its goods [103]

3.3 Applications of BMNPs in Antibacterial activity/anti-oxidant activity/anticancer activity

Bacterial infections are responsible for the most common medical disorders in all atmospheres, bringing capitals combinations to human public health [68]. Unfortunately, these agents' weak performance and overuse have led to developing drug resistance of pathogenic bacterial and fungi strains exclusively multidrug resistant strains. Infections due to these strains are higher ambitious to prevent and cure. Accordingly it is urgent to find novel antibacterial agents with high efficiency and low toxicity or alternative therapies to solve these problems. Among all the candidates used for the treatment of bacterial infections, MNPs, exclusively AgNPs, have drawn more attention because of their small size, large surface to volume ratio and tuneable Plasmon resonance properties [72] showed in table 4

Nowadays, numerous BMNPs have been synthesized and demonstrated to have significant antimicrobial potential (Table 4).

Table.4 Applications of Antimicrobial activity/antioxidant activity /anticancer activity

Biopolymer/Metal	Function of Activity	Refe-rence
Chitosan / Fe_2O_3	Antioxidant	[97]
Pectin /Fe_2O_3	Antimicrobial activity	[25]
Agarose-Fe_2O_3, Dextran-Fe_2O_3 Gelatin-Fe_2O_3	Antibacterial activity against gram-positive and gram-negative bacteria species	[10]
Dextran/sucrose Fe	Spherical E. coli, P. aeruginosa, E. faecalis, C. krusei	[98]
Agarose/dextran/gelatin Fe_2O_3	10.0 Dumbbell shape S. aureus, A. hydrophila, S. pyogenes, P. aeruginosa	[99]
Dextran/Fe_3O_4	59.0–149.0 Monitoring cancer cells of Micelles magnetic resonance imaging	[100]

Results showed that magnetic oxide N.P.s stabilized by different biopolymers have practical antibacterial effects on both Gram-positive gram-negative bacteria, such as Spherical E. *coli*, P. *aeruginosa,* E. *faecalis*, C. *krusei,* S. *aureus* and B. *cereus* (Typhii et al., 2019, [48] [98]. In addition, they also exhibited extensively antioxidant activity against Gram-positive gram-negative bacteria[12]. Other studies much use BMNPs reactive with Micelles Magnetic resonance imaging for supervise cancer cells [100]

3.4 Applications of BMNPs in biosensor and drug delivery

A biosensoring is an analytical apparatus able of changing a biological event into a physicochemical significant, which is efficient and highly specific in a low detects limit for analysis nowadays; different biosensoring detect chemicals, metal ions, proteins, etc., gas had been described. BMNPs had been extensively enforced in biosensors criteria owing to their outstanding chemical, electronic and optical, charterers. A arbitrary of the current progressive in probes and biosensing are shown in Table 5 On this basis, some BMNPs had been progressive as probes and biosensors. It had been determined that chitosan-based magnetic nanoparticles show a concentration-dependent change in the absorbance of Glucose, showing the biosensor character [89], Tyrosine [48], [90].

Traditional chemotherapeutical agents have encountered different problems such as a short lifetime in the body high toxicity, low solubility, and the high volume of dissemination, which led to a narrow the chemotherapeutical index [99]. In last the few years, BMNPs displayed enormous potential in the targeted drug delivery applications, and a summary of the current developments are shown in Table 5**.**

BMNPs was application of one common targeted delivery to transport the anti-cancer drugs to the specific sites of cancer cells. It can be detected that the metallic nanoparticles that resemble to anti-cancer drug delivery are magnetic showed with biopolymers like chitosan [90], [96]), β-cyclodextrin [91], *k*-carrageenan [93], Mannan [23] Nevertheless, PMNPs were of the applications in the delivery of biological agents still limited and more attempts should be given in this fields.

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3.5 Applications of BMNPs in biomedical

Synthesized BMNPs applications for the biomedical of hypothermic treatment of malignant tumours and a magnetic resonance imaging contrast agent [96] Various expressed a sequence of super-paramagnetic magnetic oxide (NPS) applications incapacitate in alginate in the film of health; amidst these applications, the most significant were the studies of drug release, tissue distribution, pharmacokinetics, etc. specific organ delivery and magnetic resonance imaging contrast agent. (NPs) was also most efficient for the analysis of liver cancers [47].

4. POTENTIAL APPLICATIONS IN DRUG DELIVERY DUE TO THEIR MAGNETIC PROPERTIES

The improvement of magnetic nanoparticles drug shipping ought to begin with the deserved popularity of Paul Ehrlich (1854-1915), who proposed that if an agent should selectively goal a disease-inflicting organism, then a toxin for that organism will be added at the side of the agent of selectivity [104].

The magnetic and biopolymer nanoparticles are that they may be: (i) heated in a magnetic discipline to cause drug launch or to provide hyperthermia/ablation of tissue (ii) guided or held in location via a magnetic discipline; and (iii) visualized (superparamagnetic NPs are utilized in MRI); It is essential to factor out that the latter functionality isn't confined to magnetic NPs, however additionally to different debris able to soaking up near-infrared, microwave, and ultrasound radiation. Depending at the synthesis procedure, magnetic NPs or nanocomposites may be obtained. We seek advice from NPs while the drug is covalently connected to the floor or entrapped or adsorbed in the pores of the magnetic service and biopolymer. [105]. The parameters within side the behaviour of magnetic NPs are associated with surface chemistry, length (magnetic core, volume, hydrodynamic, and length distribution), and magnetic properties (magnetic moment, remanence, coercively). Coating the NPs with an impartial and hydrophilic compound (i.e. biopolymers like; gelatin, chitosan, Carboxylate, polyacrylamide, Guar gum (G.G.), Cellulose etc.etc.) will increase the circulatory half-lifestyles from some time . Another opportunity is to lessen the particle length; however, in spite of all efforts, whole evasion of the RES does now no longer appear feasible [106] For the ones problems, superparamagnetic Fe oxide NPs (SPION), along side outside magnetic fields, appear a appropriate opportunity for drug shipping to inflammatory webweb sites via way of means of retaining suitable nearby concentrations whilst decreasing typical dosage and facet effects [107].

Traditional chemotherapeutical agents have encountered different problems such as a short lifetime in the body high toxicity, low solubility and the high volume of dissemination, which led to a narrow the chemotherapeutical index [99]. In last the few years, BMNPs displayed enormous potential in the targeted drug delivery applications, and a summary of the current developments are shown in Table 5**.**

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Arabic gum was additionally utilized to as another biopolymer for the coating and stabilization of iron compound MNPs [112]. fascinating analysis of magnetic drug targeting was conjointly performed with gelatin coated magnetic nanoparticles [113]. Gelatin can be a suitable candidate to bind with drug like antibiotic forming drug–polymer conjugate due to presence of multifunctional teams, like –NH2, –COOH in its chain.

Table 6. Potential applications in drug delivery due to their magnetic properties

Biopolymer/Metal	Function of Activity	Refe-rence
β-cyclodextrin/ chitosan/Fe	Drug delivery/ Prodigiosin delivery	[91]
Mannan / Fe_3O_4	Drug delivery	[92]
k-carrageenan/ Fe_3O_4	Drug delivery	[93]
Alginate / Fe	Reduction activity	[94]
Chitosan/ Fe_3O_4	Drug delivery	[95]
γ-Fe_2O_3/alginate matrix	Drug delivery	[96]
Medicago sativa (alfalfa)/ Iron oxide	Cancer hyperthermia, drug delivery	[108]
Gelatin-coated magnetic iron oxide nanoparticles	Drug loading and in vitro	[112]
Cyclodextrin conjugated magnetic colloidal nanoparticles	Targeted anticancer drug delivery	[113]

5. CONCLUSION

Biopolymers stabilized Fe metal nanoparticles emerge to be a competent biopolymeric biocomposite for many applications viz. adsorptions, antioxidant, antifungal activity anti-cancer activity antimicrobial activity, biosensor activity, biomedical, drug delivery, gene therapy, catalytic activity, food packaging preservation, bio imaging and property. Biopolymers are not only dependable for capping, reducing and stabilizing nanoparticles, but it is also responsible for the shape and size of Fe nanoparticles. Less task is done so far about the effect of biopolymers on the shape and size of nanoparticles. Biopolymers have been found responsible for deciding the size and shape of Fe metal nanoparticles. Even the disparity in molecular weight can affect the size of Fe metal nanoparticles. It is essential to consideration that biopolymers are responsible for the shape and size reaction temperature, reaction time, variety of method, sonication time, etc. This review will benefit those scientists working on the optimization status of Fe nanoparticles stabilized by biopolymers and their utilization.

ABBREVIATIONS

C.S.- chitosan, NPS- nanoparticle, PVA- Polyvinyl alcohol, PEG – Polyethylene glycol, PAA- Polyacrylic acid, BMNPS- Biopolymer magnetic nanoparticles.

ACKNOWLEDGEMENTS

One of the authors Prof.S. G Warkar wishes to express thanks to the Delhi Technological University Delhi India

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