A CRITICAL ANALYSIS OF THE BIOGENIC SYNTHESIS OF TRANSITION METAL NANOPARTICLES ALONG WITH ITS APPLICATION AND STABILITY

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Abstract:

Nanomaterial fabrication has been an extensive research area in the past decade, especially with managed morphologies side by side, having remarkable properties. Nowadays, naturally available substances and waste products from factories have built growing implementations in the Metal Oxide Nanoparticles (MONPs) synthesis because they can play multiple roles such as complexing agents, catalysts, capping agents, reducing agent, etc. Besides, plants, algae, fungi, yeast, virus, and bacteria are a green and safe way of creating MONPs concerning the traditional methods of using chemicals. This viewpoint includes several kinds of biogenic pathways that have been used to fabricate MONPs, the inclusion of their functions, and mechanism. This review consists of discussions of potential applications of MONPs derived from biogenic materials to store Energy, Remediation of nature, and bio-related sensors. Overall we intended to highlight the biogenic route to form transition MONPs and highlight future potentials, toxicity, and stability of MONPs.

Keywords: Transition metal nanoparticles; biogenic; application; stability.

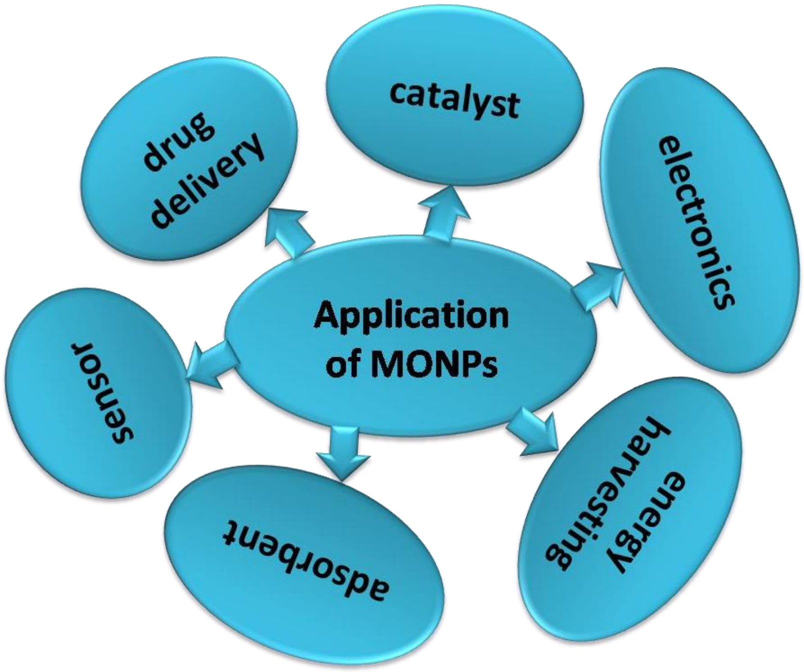
1. Introduction

Considering nanotech disclosure, various examinations have been done to create new manufacturing techniques for planning dimension and configuration managed nanoparticles that have alluring utilitarian execution. The act to plan, develop, and control the nanomaterial of size 1-100 nanometer is called nanofabrication. As a rule, nanoparticles' union may be accomplished through base-up and top-down strategies (Yuliarto et al., 2019). The top-down methodology includes a cycle of separating enormous structures to make little structures. For example, physical strategies, lithography, laser removal, faltering affidavit, beat electrochemical carving, and fume testimony is among the most ordinarily utilized top-down techniques (Barcikowski et al., 2009; Bell et al., 2001). Base-up approaches, for example, sol-gel preparing (Parashar et al., 2020),laser pyrolysis (Sourice et al., 2015), chemical vapour deposition (Nienow and Roberts, 2006), flame spray pyrolysis (Gröhn et al., 2014), thermal spray (Unni et al., 2017), and microemulsion (Okoli et al., 2012) include the combination of material. A large portion of these typically requires poisonous and brutal chemicals, such as N, N-dimethylmethanamide, sodium tetrahydridoborate, hydrazine, and some other objective circumstances, for example, elevated temperature, vacuum, and costly equipment. The techniques can bring about poisonous items that can present natural dangers to our earth; because of peak surface charge and elevated surface territory of nanomaterials, cruel synthetic compounds can soak up by the nanoparticles. Delivering all the synthetic compounds directly to nature can lead to unfavourable impacts on the living beings counting microbes, greenery, vertebrates, and spineless creatures throughout the ecosystem's different ecosystem (Kaweeteerawat et al., 2015; Sharma et al., 2019). So chemical methods are costly, time-taking, and tedious.

Consequently, it is fundamental to streamline green strategies for nanoparticle synthesis. Thus, the idea of green or biogenic synthesis initiates another age in nanotechnology. It includes the amalgamation precursor salt of nanomaterials and waste generated via industries, agriculture or microorganisms, etc. nectar is reported as the most seasoned food source in the world with remarkable clinical, physical, synthetic, and drug esteems. Nectar interceded green combination was a moderately novel idea utilized to synthesize gold and silver nanoparticles (Van fraeyenhoven et al., 2016). Taking everything into account, the green union of nanoparticles gives a basic, savvy, biocompatible, reproducible, quick, and safe technique.

The synthesis of metal oxide nanoparticles (MONPs) with nano dimensions, crystal nature, and configuration were the primary targets for studies which could be used for applications in an anticipated manner, for example, bio-clinic, biosensors, impetus used in the disposal of biotoxin bacterial along with the reduced price (Rahman et al., 2019; Yang et al., 2012). Furthermore, the synthesis of nanocomposite materials comprising a metal oxide and metals is remarkable, owing as they have characteristic optical, biomedical, catalytic, and electrically based assets (Yang et al., 2011;Azizi et al., 2016). Nanoparticles, with measurement under 100nm, such as nanosheets, nanotubes, and nanowires, have increased a lot of consideration because they have encouraging applicable parts (Smith et al., 2015; Mondal and Sharma, 2016; Wang et al., 2009). Despite interesting material and substance properties, nanoparticles go about, for instance, an extensive allying nuclear design and mass material. Distinctive synthesis strategies were used to synthesize nanoparticles with different structures and dimensions (Bosi, 2015; Kharisov et al., 1998). Apart from the truth that these techniques have brought about prevalent NPs yet a significant comprehension of the better synthetic route is needed that can be used during modern as well as trading extent for the stronger constructed, enduring, more secure, more astute items as house machines, medical, transportation, horticulture, etc. This way, the fundamental centre is to consider MONPs utilizing ecologically favourable methodologies. These give answers to the increasing provocations concerned with the problems of the environment. Nature has provided means of synthesizing cutting-edge nanomaterials and to recognize them. At present, it accounted for the research about natural frameworks; they may go about like 'bio-research facility' to form MONPs utilizing a biogenic viewpoint.

The organic methodology incorporating various microbes was utilized to combine diverse metallic nanoparticles, which have preferences more than most synthetic strategies because they are eco-friendly, vitality sparing, and financially savvy (Yuliarto et al., 2019). Biocompatibility of biogenic nanoparticles provides an extremely intriguing applicable part of biomedicine and



related fields (Figure 1) (Gupta and Mishra, 2020).

Figure1: Application of metal oxide nanoparticles (MONPs).

Current development in nanotechnology focused around eco-friendly, financially savvy synthesis route. Nanomaterials' green amalgamation is considered a green and secure method to synthesize nanomaterials utilizing nature's product. Green methodology did provide another period of shielded nanotech. Microbes like bacteria, utilized for the formation of nanomaterials such as silver, gold, tellurium oxide, etc. (Boopathi et al., 2012; Das et al., 2009; Srivastava and Constanti, 2012) while viruses were utilized to fabricate gold (Kobayashi et al., 2012; Zeng et al., 2013), palladium oxide (Yang et al., 2013), and titanium oxide (Chen et al., 2015). Moreover, fungi responded positively towards the synthesis of gold, silver, zinc oxide nanomaterials (Baskar et al., 2015; Thakker et al., 2013). Recent research uncovered the enormous green growth capability, especially in incorporating zinc oxide, gold, iron oxide, and silver nanoparticles (Prasher et al., 2018). Besides, leaf, seed extricates, root concentrates, the latex of plants, and bulbs, utilized that integrate silver, palladium, and gold NPs (Azizi et al., 2017; Jha et al. 2010; Srikar et al., 2016; Suresh et al., 2015). Despite plants, various biomolecules that have been derived from animals like silk, alginate, and chitosan were utilized to combine gold, silver, palladium, carbon, and platinum nanoparticles (Cheirmadurai et al., 2014; Deng et al., 2016; El Essawy et al., 2017). From the above literature, its concluded that biogenic route for the synthesis of MONPs is more environmentally favourable (Figure 2). Thus, in the present review, we explained briefly different aspects of the synthesis of MONPs along with its stability and applications.

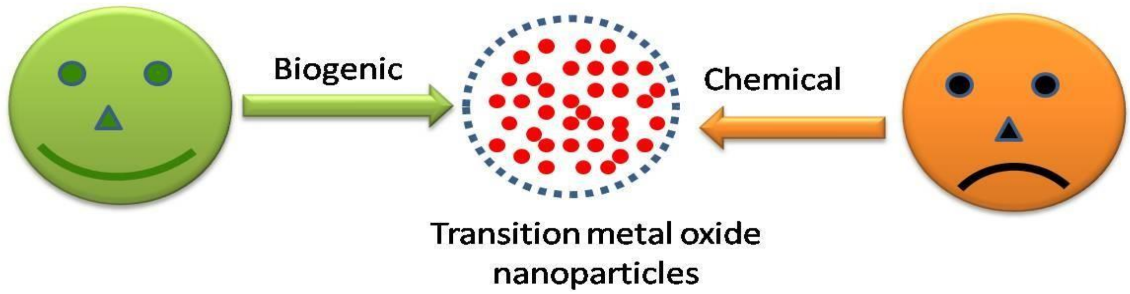


Figure 2: Schematic representation of transition metal oxide nanoparticle synthesis by the biogenic route and chemical route.

2. Green route to synthesize transition metal oxide nanoparticles:

Various microorganisms, like bacteria (Mukherjee and Nethi, 2019), fungi (Pariona et al., 2019), yeast (Eugenio et al., 2016), plant extracts (Iravani, 2011), and unwanted or waste materials (Wang et al., 2018) which worked as environment affectionate forerunner to form nanoparticles that have positive implementations. Biogenic techniques contribute to creating nanoparticles with intriguing structures with different dimensions (Adil et al., 2015), for instance, silver nanoparticles with dimensions 25±12 nm, made by uncovering the aqueous silver solution ions to fungal biomass (*Verticillium*)(Siddiqi et al., 2018). Due to electrostatic interactivity within carboxylate groups' enzymes within the fungal cell wall with silver ions, (Mukherjee et al., 2001) found the expansion of nanoparticles on mycelia surface. Since the utilization of costly chemicals is reduced, the nanoparticles developed through biogenic operations are far better than nanoparticles produced by chemical modes. Below some biogenic routes for the MONPs are discussed briefly.

2.1 By Plant:

The processing of metal nanoparticles using organisms is one of the most commonly known techniques. Among the biological materials to form nanomaterials, the greenway obtains significant attention due to its eco-friendliness, simplicity, low cost and comfortably used to form big scale and broad medicinal effects (Ghorbani et al., 2015). Furthermore, the plant extract bio compounds are chemically bound to the nanomaterials' surface, strengthen the structure and prevent their agglomeration, resulting in superficial consequences throughout the usage (Azizi et al., 2017). The nanoparticles produced by microbes were less stable with a lower formation rate than plants (Akhtar et al., 2013). Determination of silver nanoparticles formation by Cycas leaf, X-ray diffraction and transmission electron microscopy (TEM) investigation was carried out. Rietveld's study of the X-ray figures showed that the silver nanoparticles had fcc unit cell form. The surface plasmon resonance at 449 nm was discovered with ultravioletanalysis (Jha and Prasad, 2010).

Green synthesis is the watchword for the combining of plants or their metabolites with nanoparticles (NPs). In specific, this invention needs to compensate for reducing the poisonous value produced by conventionally implemented NPs. Thus, whatever metal piece may get combined by eco-friendly techniques in the sense of eco-friendly procedures used in the blending of NPs are addressed (Nasrollahzadeh et al., 2019). Green metabolic and natural materials are used in green techniques for arranging nanoparticles to use in medicinal and other implementations. A few attributing techniques and NP implementations are also checked

(Sanzari et al., 2019). Massive elements like zinc and copper are necessary for average plant growth. Still, elevated concentrations of both essential and non-essential metals can inhibit growth and signs of toxicity (Hall, 2002).

A substitute for regaining gold (III) ions from aqueous solutions and its potential to reduce gold (III) to gold (0) forming gold NPs, oat (Avena sativa) biomass was examined. To the research securing pattern of Au (III) to oat and its potential development of the gold NPs, Au (III) and biomass solution was examined at pH values ranging from 2 to 6 for a duration of 1 h (Armendariz et al., 2004). Ag metal ingestion by the plants of alfalfa from a solid medium rich in silver with the subsequent development of Ag NPs was corroborated with X-ray absorption spectroscopy and transmission electron microscopy studied (TEM)(Gardea-Torresdey et al., 2002).The stimulation of antioxidant mechanisms under metallic stress ($AgNO_3$) in Cycas had been demonstrated to contribute to AgO NPs. Comparing the formation process of silver nanoparticles involving angiosperms and gymnosperms, gymnosperms relative to angiosperms were very useful to extrapolate the formation procedure (Huang et al., 2008; Jha et al., 2009; Das et al., 2017).Consequently, plant extract biological molecules play a vital part in creating and stabilizing NPs, which is an environmentally sustainable and effective option to traditional techniques (Figure 3). Table 1, summarized used various plant species used for MONPs synthesis.

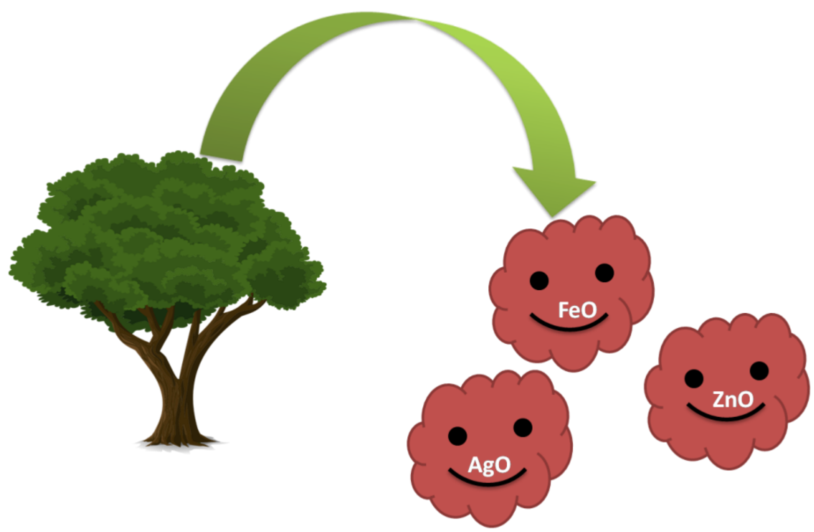


Figure 3: Schematic representation for an environmentally friendly way to prepare metal oxide nanoparticles (MONPs).

Table 1: Represents various plant species used for green synthesis of different metallic nanoparticles (Das et al., 2017).

Plant species	Plant material and solvent	Reaction temperature	Type of MONPs	Mechanism/causative agent	Size (nm)
Azadirachta indica	Kernel, water	Room temperature	Au, Ag	Azadirachtin	50–100
Camellia sinensis	Leaves, water	Room temperature	Au	Catechins, theaflavins, and thearubigins	15–42
Pinus thunbergii	Pine cone, water	Room temperature	Ag	Hydroxyl and carbonyl groups	35
Nelumbo nucifera	Leaves, water	Room temperature	Ag	Not mentioned	25–80
Lemongrass plant extract	Leaves, water	Room temperature	Au	Sugar derivative molecules (not specified)	200–500
Avena sativa	Stems, water	Room temperature	Au	Not mentioned	5–85
Aloe vera	Leaves, water	Room temperature	Ag	Not specified	70
Pinus resinosa	Bark, water	80 ℃	Pb	Fulvic acid	16–20
Ginkgo biloba	Leaves, water	25–95℃ room temperature	Ag Au	Proteins and metabolites	15–50
Alfa sprouts	Living plant	Not applicable	Ag	In situ synthesis	2–20
Syzygiumaromaticum	Flower buds, water	Room temperature	Cu	Eugenol (not specified)	5–40
Cintella asiatica	Leaves, ethanol (70%)	Room temperature	Au	Phenolic compounds (not specified)	9.3 and 11.4
Camellia sinensis	Leaves, water	Room temperature	Pt	Pure tea polyphenol	30–60
Asparagus racemosus	Tuber cortex, water	Sunlight	Pd	Bioactive compounds (not specified)	1–6
Camellia sinensis	Leaves, water	Room temperature	Fe_2O_3	Polyphenols	5–15
Nephelium lappaceum L	Peels, hydro-ethanol	80 ℃	NiO	Nickel–ellagate complex formation	50
Nephelium lappaceum L.	Peels, hydro-ethanol	80 ℃	MgO	Not mentioned	100
Aloe barbadensis	Leaves, water	150 ℃	ZnO	Phenolic compounds,	25–40

miller				terpenoids, or proteins (not specified)	

2.2 By Algae:

Green metallic nanoparticle synthesis is based on the three principle criteria, i.e., green, reducing agent, admissible solvent system, and stabilizing agent (Sau and Murphy, 2004). Among all the eco-friendly nanoparticle synthesis route, algae are one of the largest photoautotrophic group of microorganisms. Microalgae are recognized as good food. They are abundant in lipids, minerals and specific vitamins, and similarly plentiful biomolecules like proteins, polysaccharides, and polyphenols, with potential therapeutic usages in contradiction of oxidative stress and cancer allergy, hypertensive, etc. (Zuercher et al., 2006). Algae are known to be efficient competitors regarding metal accumulation which makes them suitable candidates to form NPs.

Moreover, algae are relatively easy to handle, eco-friendly, and less toxic with almost zero risks to the environment. Additionally, they serve as nanobiofactories for metallic nanoparticles (MNPs) synthesis due to the high cultivation rate in less time (Khanna et al., 2019). Their phytochemicals comprise carboxyl, hydroxyl functional group, and amino acids, which function as efficient metal-reducing agents and coating agents that provide strong capping on metal NPs in one step (Namvar et al., 2015).

Microalgae showed enormous potential in the biosynthesis of different metallic and metal oxide NPs such as silver (Ag) (Barwal et al., 2011), gold (Au)(Suganya et al., 2015), palladium (Pd)(Lengke et al., 2007), zinc oxide (ZnO)(Singh et al., 2014), etc. The existence of proteins, polysaccharides, and polyphenols in the algae may reduce the metal ions and form metal NPs (Ghorbani et al., 2015).

The method involved in the synthesis of nanoparticles through algae was generally the result of the reaction between the fluid algal extract and metal solutions. As a consequence, nuclei are formed, accompanied by changes in the shade of the reaction. Leading to surface plasmon movements with MNPs, individual colour variations emerge with varied in size and shape (Fawcett et al., 2017). pH, temperature, concentration, and duration are the bioactive components present in a sample responsible for the production of the NPs and the conditions that regulate the reaction. There are two paths of NPs synthesis, i.e., intracellular and extracellular. The intracellular word points out the mechanism within the cell (Sharma et al., 2016). It concerns the NADPH or NADPH dependent reductase enzyme which acts as a reducing agent generated by the Electron transport system (ETS) or by ETS at thylokoid membrane or the cell wall. The microalgae not required pretreatment because it depends on the metabolic pathway, i.e.,photosynthesis, respiration and nitrogen fixation. In *Rhizoclonium fontinale* and *ulvaintestinales* to produce gold NPs intracellularly when exposed to hydrogen tetrachloride aurate solution for 72 hours at 20℃, they shift the shade of its thallus from green to purple, thereby creating AuNPs. All these mechanisms confirmed the fact that no shade alteration happens after the gold solution is implanted with dried plant material, which means that the bioreduction mechanism did not contribute to either of the metabolic pathways including enzymes or other metabolites and that the cells of the genera died after transforming Au (III) to Au (0)(Parial et al., 2012). Microalgae are pre-treated by washing and blending before NPs synthesis is compulsory (Dahoumane et al., 2016). In enzymes' existence, it interacts with the metal ions stuck on the cells' surface and reduces them. Active spirulina planters biomass has been consumed to shape gold nanoparticles with a mean size of about 20-30 nm. For gold uptake

Process, based on the time it is carried out in two stages, the first stage is the rapid stage wherein metal ions are easily stuck on the algae cell surface. Metal ions pass the cellular cellulose wall in the slow stage by the cell's transport mechanism (Kalabegishvili et al., 2012). Extracellular gold particle formation with a scale >20nm, spherical were synthesized using *Lyngbya majuscula* and *spirulina subsala* (Chakaraborty et al., 2009). Macroalgae Sargassum wighttii for the formation of Au nanoparticles extracellularly was successfully prepared with a diameter ranging between 8 to12 nanometre (Singaravelu et al., 2007). Table 2, incorporated some reported work on NPs synthesis by algae.

Table 2: A brief description of the latest studies on the algal formation of metal NPs.

Types of Nanoparticles synthesized.	Organism/s	Size (nm)	Reference
Au Au Ag	Spirulina platensis IPPAS B-256 Sargassum muticum Chlorella pyrenoidosa	3-20 8-12 8 ± 2	(Kalabegishvili et al., 2012) (Singaravelu et al., 2007) (Aziz et al., 2015)
Ag Cu	Botrycocus braunii	40-100 10-70	(Arya et al., 2018)
ZnO	Sargassum muticum	30-57	(Azizi et al., 2014)
Au	Phormidium valderianum	15	(Parial et al., 2012)
CdS	Phormidium tenue NTDM05	5.1±0.2	(MubarakAli et al., 2012)
Ag	Chlorella vulgaris	44±6	(Xie et al., 2007)
Au	Chlorella vulgaris	9-20 single - crystalline	(Xie et al., 2007)
Au	Plectonema borya num UTEX 485	Spherical <300	(Lengke et al., 2007)
Ag	C.Calcitrans	53.1-71.9	(Merine et al., 2010)
Ag	Pterocladia	7-20	(El-Rafie et al., 2013)
Au	Shewanella algae	10-20	(Kupryashina et al., 2013)
Ag	Chlorella vulgaris /Scendesmus obliquus	8.2±3/ 8.8±2	(El-Sheekh and El-Kassas, 2014)
Pd	Sargassum bovinum	5-10	(Momeni and Nabipour, 2015)

Ag	Alphanothece spp	44-49	(Sudha et al., 2013)
Ag	Sargassum muticum	5-15	(Azizi et al., 2013)
Ag	Anabena sp.66-2	24.13±2	(Patel et al., 2015)
CuO	Bifurcaria bifurcata	5-45	(Abboud et al., 2014)
Ag	Sargassum longifolium	40-85	(Rajeshkumar et al., 2014)
Ag	Caulerpa racemosa	5-25	(Kathiraven et al., 2015)

2.3 By Fungi:

Fungi have possible techniques to improve the economic efficacy of extracellular nanoparticles synthesis. The need of improve stable, cost-effective and eco-friendly nanomaterials formation technologies have received growing interest in nanoparticle biosynthesis. An efficient, reducing agent for biosynthesis has been lower NADH, and silver nanoparticles' production can be an extracellular interaction method. Besides, silver nanoparticles' antibiotic capacity, counting fungi, and bacteria may help suppress various pathogenic organisms (Li et al., 2011).

Honary et al. synthesized Ag NPs on Penicillium Citrinum colony, with uniform spherical size (104 nm) (Honary et al., 2013). A new biological method has been reported for the production of Ag nanoparticles employing verticillium fungus wherein Ag particles have been produced underneath the layer of the fungal cell wall, possibly due to the interaction of metal ion enzymes found in the cells have been able to expand as Ag nanoparticles have been biosynthesized (Mukherjee et al., 2001). Therefore, discovering energy-saving, environmentally safe, and renewable ecological synthesis procedures to form nanomaterials is a continuing draw for interest in this area. The microbial formation of noble NPs satisfies criteria under ecological building technology, and research has shown that many microorganisms may transform metal ions to nanomaterials (Siddiqi and Husen, 2016). Table 3, summarized NPs synthesis by various fungal species.

Table 3: Representations of fungi used to synthesize various metallic nanoparticles by green methods (Yadav et al., 2015).

Fungal species	Nanoparticle	Test Object	Size and shape (nm)	Observed effect in the presence of nanoparticles
Phoma glomerata	Ag	Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa	60-80	The activity of vancomycin was the most increased. An increase of activity was more prominent against Gram-negative bacteria

Trichoderma viride	Ag	S. aureus, E. coli, Micrococcus luteus, Salmonella typhi	5-15	All tested combinations showed a beneficial effect, especially in amoxicillin. An increase in activity was more significant against Gram-negative bacteria.
Ganoderma Lucidum	Ag	S. aureus, E. coli	10-70	Activity increased
T. viride	Au	S. aureus, E. coli, VRSA	4-15	Against VRSA activity increased; appeared activity against E. coli
Pestolotia sp.	Ag	S. aureus, S. typhi	10-40	The activity of both antibiotics increased, especially of gentamycin
Trichoderma harzianum	Ag	S. aureus, E. coli	30-50	Activity of both antibiotics increased
Aspergillus terreus, Paecilomyceslilacinus, Fusarium sp.	Ag	S. aureus, E. coli	5-50	Increases in activity of erythromycin, methicillin, chloramphenicol and ciprofloxacin, more prominent against S. aureus and S. pyogenes

2.4 By yeast:

Due to the simplicity of the handling of yeast under lab conditions, the production of abundant enzymes, and the rapid expansion with modest resources, yeast's possible use in nanoparticles' green synthesis is favourable. Another advantage while using the sustainable strategy by using yeast to synthesize metal-based nanoparticles is cost-effective permanence and potential for biomass usage. Biomass yeast creates metal NPs by reducing proteins within enzyme either by extracellular or intracellular methods. For example, the reduction activity of proteins is related to many functional groups-OH, -C=O, -NH_2, -S-S-, C-O-C, and C-N-C that provide the flow of electrons to ions for the synthesis of metal NPs (Moghaddam et al., 2017). A few studies have documented the possible applicability of metal-based NPs synthesized using yeast. S. pombe was used for intracellular sulphide NPs to process diode cadmium, which displayed low-voltage activity and high forward current value. These properties are meant to make the artificial framework a supreme diode (Kowshik et al., 2002). Also, yeast strains have been utilized to synthesize NPs of Ag and Au. Ag nanoparticles were extracellularly synthesized in a study using the Ag resistant yeast strain MKY3, where hexagonal silver NPs of size 2 to 5 nm were formed in the log growth phase. Yarrowia lipolytica cells were incubated with altered amounts of chloroauric acid and nanoparticles of cell-linked gold and nanoplates were formed. Also, it has been reported that the number of cells and the salt concentration used will influence the size of formed nanoparticles (Pimprikar et al., 2009). In a similar study, zirconium phosphate was accompanied by mesoporous morphology formed using yeast as a bio-based model. As an air electrode, these biosynthesized nanoparticles were added to demonstrate exceptional electrical, catalytic oxygen reduction activity (Tian et al., 2010). The Zn_3 $(PO_4)_2$ dust were shaped microstructure like a butterfly with a size varying from 10-80 nm in width and 80-200nm in length by yeast as bio template(Yan et al., 2009). In another analysis, ZnO nanoparticles were synthesized with the hexagonal wurtzite form and average crystallite size around 10 to 60 nm by Pichia kudriavzevii yeast strain excellent antimicrobial, antioxidant activities. Table 4 shows different metal-based nanoparticles prepared by yeast.

Table 4: Representations of yeast used to synthesize various metallic nanoparticles by green methods

Yeast	Nanoparticle	Size (nm)	Shape	Localization	Application	References
Pichia jadinii (Candida utilis)	Au		Various	Intercellular	-	(Gericke and Pinches, 2006)
Yarrowia lipolytica NCIM3589	Au	Various	Particles and plates	Cell surfaces	-	(Pimprikar et al., 2009)
Yeast strain MKY3	Ag	2-5	Twinned or multitwinned, some hexagonal	Extracellular	-	(Kowshik et al., 2003)
Schizosaccharomyces pombe	Cds	1.8, 2.9	-	Extra- and intracellular	-	(Dameron et al., 1989)
Candida glabrata	Cds	2, 2.9	Hexamer	Extra- and intracellular	Physiological	(Dameron et al., 1989)

Schizosaccharomyces pombe	Cds	1-1.5	Hexagonal	Intracellular	-	(Kowshik et al., 2003)
Candida glabrata	Cds			Intracellular	-	(Krumov et al., 2007)
Yeast	Zr		Irregular mesoporous	-	Fuel cells	(Tian et al., 2010)
Pichia kudriavzevii	ZnO	10–61 nm	Hexagonal Irregular	Extracellular	Physiological	(Moghaddam et al., 2017)
Yeast	$Zn_3(PO_4)_2$	10–80, 80–200	Rectangular	Extracellular	Antirust pigment and electronic luminophore	(Yan et al., 2009)

2.5 By Bacteria:

Bio-inspired synthesis with bacteria has essential economic advantages and ecological performance and a renewable, non-toxic and economical alternative, concerning traditional methods in the assembly of nanomaterials that use dangerous and hazardous resources. Besides, bacteria can be used for heavy metal ion bioreduction as well as recovery. As effective biofactories, Bacterial cells have a considerable capacity to reduce metal ion that may get obtained as nanocrystals of diverse structures and dimensions (Iravani and Varma, 2020). Liu et al. initially made synthetic bacteria that capture heavy metal. The synthetic strain of Escherichia coli was developed from the design of an iscSAU/moaEDAB-based synthetic sulphur metabolism opera (SSMO). Photoelectron X-ray spectroscopy (XPS) shows a re-design of the sulphur and heavy metal resistance ability of synthetic bacteria with EcSSMO cells more surviving than Ec0 (Not comprising SSMO) control cells with 50 mg/L of Pb^{2+} and Cd^{2+} (> 92% vs. 10%)(Figure 4)(Liu et al., 2021).

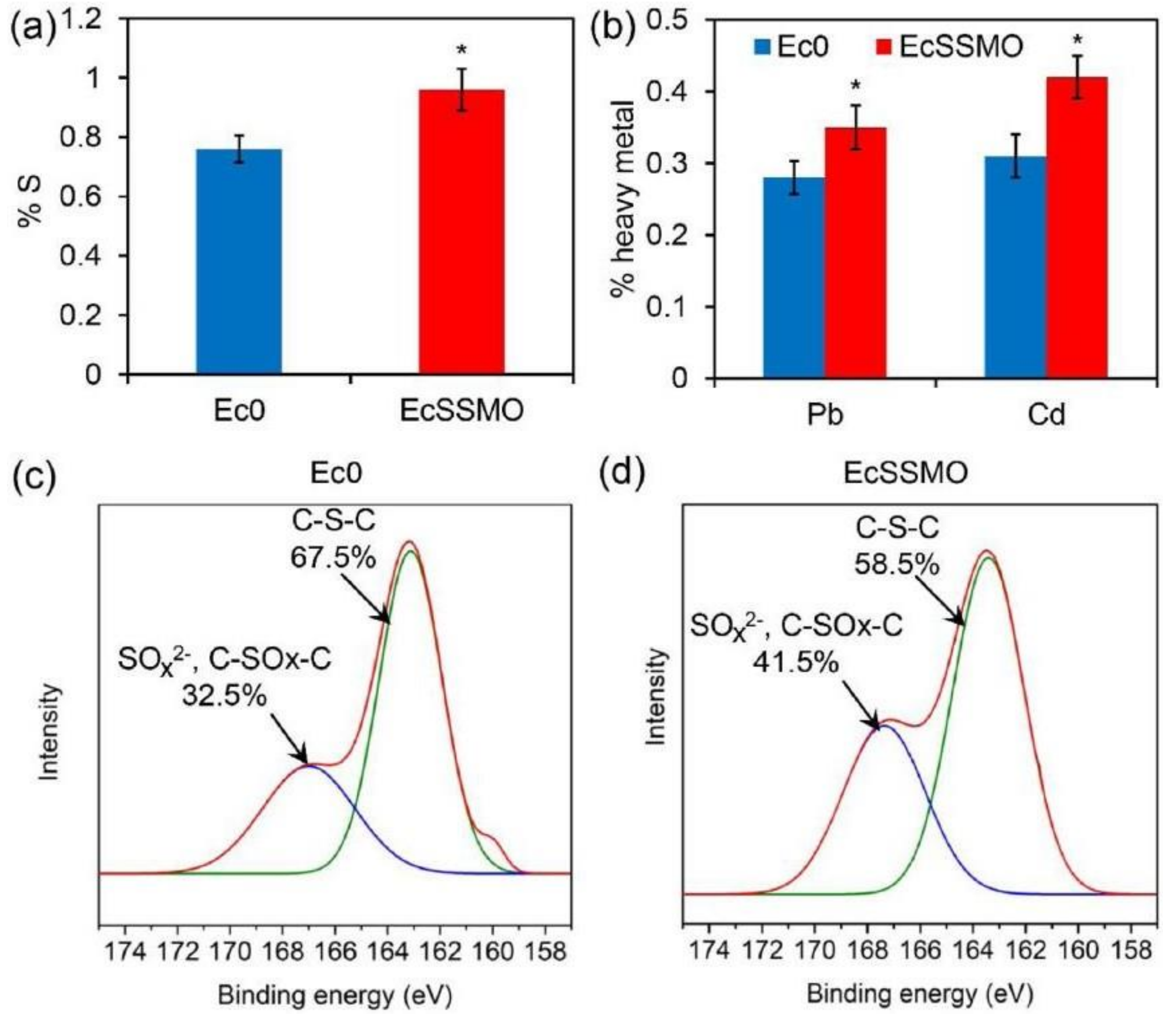


Figure 4: XPS analysis of the Ec0 and EcSSMO cells treated by Pb^{2+}/Cd^{2+} (Pb^{2+} 50 mg/L, Cd^{2+} 50 mg/L). (a) Intracellular S content (atom percent). (b) Intracellular heavy metal contents (atom percent). (c) XPS spectra of the sulfur element in Ec0 cells. (d) XPS spectrum of the sulfur element in EcSSMO cells. (Liu et al., 2021). (Reprint with permission Elsevier).

A combination of microscopic and spectroscopic methods characterized the synthesized AgNPs. It validated the silver nanoparticles with a surface plasmon resonance having peaked at 420 nm with particle size 41 to 68 nm.I*n-vitro* antibacterial activity of silver NPs have exhibited possible antibacterial properties in case of multidrug unaffected by the pathogens like Salmonella typhi and Staphylococcus aureus (Prasher et al., 2018).

Chemotherapy, surgical operations, and radiation are major cancer medications. Still, their most significant drawbacks are non-precisely prescribed antitumor drugs, inconsistent drug delivery to the drug doses' tumour delivery, and low monitoring. Nanoparticles are rapidly developing nanomedicine sector included in cancer therapy (Pugazhendhi et al., 2018). When C2C12 cells were presented to Pt nanoparticles, *in-vitro* cytotoxicity showed a major fixation subordinate reduction in cell feasibility. In comparison, in MG-Pt NP-treated cells, protein expression of both(i) apoptosis-related proteins, for example, case-3 and case-9, (ii) inflammatory response proteins like TNF-α, TGF-β and NF-κB are significantly improved. The absorption and intracellular colonization of MG-Pt nanoparticles induced by autophagosome aggregation in C2C12 cells and bacterial cells indicate that synthesized nanoparticles allow rapid cell apoptosis (Subramaniyan et al., 2018).In the current scenario, several NPs with a definite chemical composition, size, and structure are produced by various bacteria, whose uses have been investigated in several cutting-edge research fields. In below table 5, bacteria generated NPs were summarized.

Table 5: Representations of bacteria used to synthesize various metallic nanoparticles by green methods (Velusamy et al., 2016).

Bacterial	Nanoparticle	Location	Size of nanoparticles (nm)
Pseudomonas aeruginosa	Au	Extracellular	15-30
Pseudomonas stutzeri	Ag	Intracellular	200
Bacillus subtilis	Ag and Au	Intracellular and extracellular	
Shewanellaoneidensis	U	Extracellular	150
Lactobacillus sp.	Ag and Au	Intracellular	60
E. Coli	CdS	Intracellular	2-5
Clostridium thermoaceticum	CdS	Intracellular and extracellular	2-5
Rhodopseudomonas	Au	Extracellular	10-20
E. Coli DH5□	Au	Intracellular	25-33
Thermomonospora spp.	Au	Extracellular	8
Streptomyces albidoflavus	Ag	Intracellular	10-14
Klebsiella	Ag	Extracellular	5-32

2.5 By Virus:

The utilization of biomolecules, fabrications, and methods to grow inorganic material production continues to provide new and fascinating solutions to the current synthetic methods. Tobacco Mosaic Virus (TMV) is a surprisingly robust virion that stays unchanged at temperatures of up to 60℃ and between 2 and 10 pH values(Bruckman and Steinmetz, 2014). Every virus morsel contains about 2130 kind of same genetic information of protein organized around a single strand of RNA in a helical pattern to create a hollow protein tube with a 4 nm-wide central channel, 300 '18 nm in duration (Aumiller et al., 2018). The latest technique to the template-directed the formation of inorganic-organic nanotubes with the help of TMV is reported in this article (Shenton et al., 1999).

The development and production of viral films can be processed without a bacterial infection for several months. They can be used in medicinal applications for the treatment of high-density engineered DNA. Animal viruses for material research, genetics, and gene therapy have been developed for several years. Recently, pathogens counting viruses specific to the plants, have been used in nano-biotechnology due to their relative morphological and enzymatic stability, ease of processing with non-toxic and pathogenic. The assembly and connecting of novel nanosized components through biologic scaffolds (viruses), enables structured assemblies to interact with advanced technologies such as prints that nanotechnology produces. For example, the cowpea mosaic virus (CPMV) makes an excellent molecular compound in nanoscale devices because of its size, monodispersed, and different chemical groups (Velusamy et al., 2016). Table 6, incorporate several virus oriented NPs with different size.

Table 6: Representations of the virus used to synthesize various metallic nanoparticles by green methods

Virus type	Nanoparticle type	Size (nm)	References
Tobacco mosaic virus (TMV)	SiO_2, CdS, PbS and Fe_2O_3	ND	(Shenton et al., 1999)
TMV	Palladium (Pd)	1-2	(Yang et al., 2013)
TMV	Copper	3	(Balci et al., 2006)
TMV	Gold	5	(Kobayashi et al., 2012)
M13	Titanium dioxide	20-24	(Chen et al., 2015)
□ −annulus peptide	Zinc oxide	48±25	(Fujita and Matsuura, 2014)

3. **Stability**:

Although naked nanoparticles are fragile in solution, so to increase the stability of NPs we must use stabilizing agents in all methods of preparation, i.e., surfactant, polymer, dopant, etc. (Choi et al., 2004; Hwang et al., 2008). These stabilizing agents attach to the surface of nanoparticle during preparation and inhibit their further agglomeration. Stabilization of NPs can be classified into three categories:

A. Electrostatic stabilization: In electrostatic stabilization ions generated from starting material and attach to the NPs and generates coulombic repulsion to inhibit agglomeration and increases stability (Hang et al., 2009).
B. Steric stabilization: The big molecules like surfactants and polymers inhibit agglomeration via adsorption, creates steric stabilization (Lourenco et al., 1996).
C. Electrostatic stabilization: The electrostatic stabilization includes both steric and electrostatic stability (Yeap et al., 2012). For example, polymers generate a steric effect, but sometimes they bound weakly to the surface of NPs (Ueno et al., 2008), such as polyvinylpyrollidone is widely

found in several other polar solvents due to its environment-friendly and soluble nature. Partial part of polyvinylpyrollidone can quickly adsorb on the surface of NPs, and the rest part gets dissolves quickly generating a second defensive shield in the suspension (Murshid and Kitaev, 2014; Narayanan and El-Sayed, 2003).

4. **Application**:

Because of low toxicity, adaptable synthesis route, and cheap process transition metal influenced reaction represented an essential and wide field of study(Santhanam, 1996). Nowadays, there is massive effort use to upgrade current precious metal with affordable price transition metal nanoparticles. More pertinently, there are plenty of unusual reactions mediated by transition metals. Here, the transition metal-induced several applications are discussed in brief.

4.1 **Drug delivery**:

Due to cancer treatment possibilities and therapies of various diseases, managed drug release of workable nanomaterial is popularized with growing interest. One of the foundations of cancer therapy is the targeted delivery of anticancer medications, since it may make for greater treatment efficacy and fewer adverse effects. Magnetic drug targeting is a powerful drug delivery strategy that can be realized if a drug delivery device has a good magnetic moment(Chee et al., 2018).

More interest has been created in recent years by the ability of MONPs to attach a wide variety of organic molecules, whose low toxicity and robust and tunable diffusion made it more efficient for drug delivery. In addition to this, its distinguishing features, such as biodegradable, non-toxic, biocompatiable have presented innovative drug delivery solutions (Arruebo et al., 2007; Price et al., 2018). MONPs are also successful used for gene therapy (McBain et al., 2008). The combination of antibiotics with MONPs helps develop the effective antibiotics (Cristea et al., 2017; Xu et al., 2019). Conjugation of methotrexate with AuNPs, showing the association of the carboxylic class of drugs on the surface of the metal of Lewis lung carcinoma cells reported to have better drug concentration levels (Dreaden et al., 2012). MONPs layers ought to be changed to avoid agglomeration and improve the performance of MONPs for the delivery of drugs (De Jong and Borm, 2008).

4.2 Sensors

MONPs synthesized via green sources are being studied and preferred for biosensing application over chemically synthesized MONPs. The biosensing capacity of NPs synthesized via the biogenic route is a better option than from other sources. Eco-friendly gold nanoparticles production has proven to play a vital role in detecting hormone from urine samples among pregnant women (Kuppusamy et al., 2014). It was excessively used in the prevention of allergy, heart failure, hypertension, adrenaline. Pt NPs were used as a special high sensitivity biosensor for evaluating adrenaline (Brondani et al., 2009).

4.3 Manufacturing and materials:

The NPs is the representation, preparation and construction of natural and non-organic structures < 100 nm, which exhibit unique and novel functional properties. Although characteristics of MONPs digress in a dimension ward way from real mass content, nanocrystalline materials offer material science extremely interesting materials.
Assembling NPs display physicochemical features with excellent electrical, electronic, optical and imaging characteristics widely sought after in particular pharmaceutical, industry and biomedical applications (Mir et al., 2018;Ibanez et al., 2018). Numerous manufacturers have reported nanotechnology's anticipated benefits at high and low levels, and desirable products are now being mass delivered, such as microelectronics, aviation, and drug firms (Weiss et al., 2006). In various industries, including food handling and pressing, nanotechnology has been marketed (Liu et al., 2018). The proximity of NPs to economically accessible objects is becoming increasingly common. For example, Metals NPs, like Au and Ag, have various hues depending on plasmon reverberation in the visible field due to aggregate electron motions beyond NPs (Liu et al., 2018; De Matteis et al., 2020). The solid reverberation frequency depends on the size and state of NPs, the isolation of interparticle, and the dielectric property of the medium surrounding it. A wide range of applications, including synthetic sensors and biosensors, have misused the excellent plasmon absorption highlights of these reputable metals NPs (Jana et al., 2016).

4.4 Environment:

During the preparation and application of MONPs sometime, constructed NPs prompts particular materials' arrival into the environment. The risk evaluation of these NPs in the environment requires an understanding of their mobility, reactivity, eco-damage and persistence (Kumar et al., 2014; Sikder et al., 2020). The application of NPs in infrastructure materials was extend the convergence of NPs in groundwater and soil, which is the most effective way to determine ecological hazards (Guerra et al., 2018; Nasrollahzadeh et al., 2019; Patanjali et al., 2019). Due to the high surface to mass ratio, distinctive feature NPs presume that a notable feature may be integrated to the outside of NPs in the strong / water parcelling of pollutants, co-encouraged during the assembly of typical NPs or trapped by the conglomeration of NPs with contaminants adsorbed to their surface. NP features, such as scale, arrangement, morphology, porosity, conglomeration/disaggregation, and overall composition, are subject to the collaboration of pollutants with NPs. The luminophores are undependable and insulated from environmental oxygen while they are doped within the organization of silica. The bulk of nanotechnology's ecological applications fall into three classes:

A. Environmental friendly and sustainable product in a biogenic way.
B. Recovery of debased goods for toxic chemicals
C. Detectors for (Ge et al., 2019) ecological stages (Tratnyek and Johnson, 2006).

The expulsion from daily water of significant metals such as mercury, lead, thallium, cadmium and arsenic has been impressively taken into account because of their detrimental impact on ecological and human well-being. For this destructive, fragile substance, superparamagnetic iron oxide NPs are a viable sorbent material. In this way, due to the non-appearance of structural strategies, no estimates of constructed NPs in nature have been available, ready to quantify following the grouping of NPs (Mueller and Nowack, 2008). NP photodegradation is also a fundamental practice and, for this reason, various nanomaterials are used. For photodegradation purposes, Rogozea et al. used NiO/ZnO NPs modified silica in the pair style. A similar conference unveiled the amalgamation of the spectrum of NPs and announced their applications for mechanical, brilliance and debasement (Yaqoob et al., 2020; Zhu and Zhou, 2010). Semiconductors metal oxides were also used for gas detection implementations due to their electrical conductivity's affectability to the extensive gas component, arising from accusations of shifting partnerships of receptive gases (Ge et al., 2019; Swain et al., 2018).

4.5 In electronics:

In the last few years, there has been an increasing excitement for the development of printed gadgets because printed hardware provides enticing silicon methods and the potential for limited effort, massive zone hardware for adaptable presentations, sensors. For e.g., metallic NPs, natural electronic atoms, CNTs, and pottery NPs, printed hardware with various functional inks containing NPs have been relied on to stream rapidly as a large-scale production measure for new varieties of electronic gear (Kosmala et al., 2011; Nayak et al., 2019). Impressive one-dimensional semiconductor and metal auxiliary, optical, and electrical characteristics make them the main fundamental square for another era of electronics, sensors and photonic materials (Dwivedi et al., 2015; Lah et al., 2018). Simple control and reversible selection are the essential characteristics of NPs, taking into account the probability of fusing NPs in electrical, mechanical, or optical gadgets, such as' 'base up' or'' self-get together (Zhang et al., 2019).

4.6 Energy harvesting:

Ongoing reports have warned us of the constraints and scarcity of petroleum derivatives due to their non-renewable origin for a very long time to come. In this way, researchers shift their discovery processes at a modest cost to generate renewable power sources from easily available assets. Because of their enormous surface area, optical activity, and reactant nature, they find that NPs are the best possibility for this reason. NPs are usually used to generate vitality from photoelectrochemical (PEC) and electrochemical water separation, especially in photocatalytic applications (Chen et al., 2020; Li et al., 2020). Electrochemical CO_2 reduction to power precursors, sun-based cells, and piezoelectric generators also presented advanced options to achieve vitality in addition to water separation. Besides, NPs use vitality stockpiling applications to conserve vitality in diverse nanoscale systems (Hu et al., 2015). As of late, nanogenerators are made, which can turn to power using piezoelectric over mechanical vitality, which is an unstable way to deal with vitality production (Wang et al., 2015; Zhu et al., 2013).

In photovoltaics, metal oxide semiconductors were used either as a photoelectrode in colour sharpened sun-oriented cells or to create p-n intersections metal oxide. Nanomaterials can be used as electrodes and scattering/light-trapping layers, as well as nanoparticles-based electron transport layers in solar cells (Djurišić et al., 2014; Szostak et al., 2018). The field of emerging photovoltaic solar cells demands materials with a plurality of functions, and these are difficult to be found in just one component (Mahmood et al., 2020). TiO_2, ZnO, and Nb_2O_5 are the best applicants as photoelectrodes because of their high synthetic and warm soundness, opening blocking properties, and reasonable electron selectivity(Kim et al., 2016). Nanochemistry and nanomaterials have various opportunities for a new generation of photovoltaics with high solar energy conversion efficiencies at low processing costs. Over a wide range of the spectrum to harness photons can optimized Quantum-confined nanomaterials and polymer-inorganic nanocomposites. Simultaneously, plasmonic architectures have powerful ways to minimize the thickness of layers that absorb light (Chen et al., 2013). The Solar Cell has shown that nanotechnology can greatly boost solar photovoltaic, solar thermal, and solar-to-fuel technologies, while there is much further research and development to be done.

5 **Conclusion**:

In the last decade, significant strides in NP synthesis have been made. There are reproducible methods, with strong control over scale, shape and composition, for making organized NPs. In this respect, about bottom-up synthesis and product production, NPs can still fulfil nanotechnology promises. The case is less optimistic as far as catalysis is concerned. The NP suspension is also merely a reservoir for metal atoms/ions leaching into solution. This leaching in separate reactions is now proven for many forms of NP suspensions. For this explanation, researchers reporting NP catalysis must also convince their readers from now on that the actual catalysts are the NPs. Some of the drawbacks of MNPs are the particular mechanism to be elucidated for the synthesis of NPs, limits to the scale-up of manufacturing processes, and process reproducibility. The biological synthesis of MNPs has always been advantageous. In particular, green synthesis of MNPs using plants and their extracts is more inexpensive, energy-efficient, and environmentally sustainable, as needed in therapeutic applications, and is free of toxic pollutants. Microbes are considered possible biofactories to synthesize MNPs and serve their unique physicochemical properties, a new class of antimicrobial agents. In pharmacy, MNPs have established numerous applications as direct therapeutic agents to treat ailments and as carriers for drug delivery systems. In both cases, the critical areas where researchers need to focus on are the stability and surface operation of MNPs. In particular, to consider the benefits of this method, creating a logical protocol for green synthesis of MNPs; the use of these particles to solve environmental problems should be strongly oriented in the future.

Conflict of interest

Authors declare no competing financial interest.

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