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BIOGENIC SYNTHESIS OF MANGANESE NANOPARTICLES: A REVIEW

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ABSTRACT

Nowadays, nanotechnology is the emerging field of medical research. Nanoparticles are intermediate structure between micro materials and atomic structures which are responsible to enhance the physical properties such as surface area, volume ratio caused more attention to many technological, environmental, and medical challenges. Today, green synthesis of different nanoparticles (NPs) using plant extract, synthesis using microorganism, and low-temperature synthesis has been extensively studied. However, less attention has been paid to manganese as a high performance metal in various applications such as medicine, biomedicine, biosensors, water treatment and purification, electronics, electrochemistry, photo electronics, catalysis etc. Manganese (Mn) is a transition metal, existing in oxidation states of -3 to $+7$; however, the most common are $+2$, $+3$, $+4$, $+6$, and $+7$. Manganese oxides (Mn-oxides) has wealthy structures such as MnO , Mn_5O_8 , Mn_2O_3 , MnO_2 , and Mn_3O_4 , and can be used in a variety of fields. Mn-oxide NPs potentially hold great promise for sustainable nanotechnology. This review attempts very recent research findings to summarize the data for green synthesis, applications and future perspective of Mn NPs. Also, various applications of the green synthesized Mn NPs have been reviewed.

Keywords: Metal nanoparticles, Mn NPs, Plant extract, Green synthesis, Metal reduction

INTRODUCTION

Nanotechnology has shown explosive growth worldwide in the past few years in the development of engineered nanomaterials with a wide range of applications in various fields ranging from material sciences to biomedicine [1]. Nanotechnology is appearing as a new field of research dealing with preparation of nanomaterials and nanoparticles (NPs) for their applications in diverse fields due to their highly multifunctional, modular, and efficient properties such as food technology, healthcare, optical devices, space industry, pharmaceuticals, cosmetics, electrochemistry, modify membrane, textile industry, water treatment and purification, water supply systems, biomedicines, mechanics, optics, energy science, catalysis, sensors, electronics, and, etc. [2–9]. Metal nanoparticles are synthesized and used because of their unique electrical, optical, catalytic, and magnetic characteristics [10–11], which differ from the characteristics of bulk materials. These involve the mild pH, pressure, and temperature for biosynthesis of NPs and do not include harmful or hazardous substances and prohibit the addition of external reducing, capping, and stabilizing agents [12].

PLANT MEDIATED SYNTHESIS OF Mn NPs

Manganese is the most abundant element of the earth, as Mn is the twelfth most common element on the planet and the third most abundant transition element. Mn-oxides can be used in molecular sieves, solar cells, batteries, catalysts, magnetic materials, optoelectronics, drug delivery ion-sieves, as well as other fields such as imaging contrast agents, magnetic storage devices, water treatment and purification. In the biological synthesis of Mn NPs, raw materials, vegetables and fruits, plant extracts, microbes, and fungi are utilized to prepare Mn and Mn-oxide nanoparticles. Biogenic methods for synthesis of manganese nanoparticles and its potential application are described in **Figure 1**.

Present review is aimed to describe plant mediated biogenic synthesis of Mn nanoparticles. In the synthesis of NPs employing plant extracts, the plant extract is simply mixed with the metal salt solution at ambient temperature and the reaction is complete in a few minutes. The metal reduction is attributed to the different compounds which are present in the plant extract such as polysaccharides, terpenoids, flavones, and phenolics [13]. So far, several

plant extracts have been used in the synthesis of manganese NPs.

A simple pictorial representation of plant extract mediated Mn NP synthesis is shown in **Figure 2**. Plant extract mediated

green synthesis is a one step process for synthesis of Mn NP because the phytochemicals themselves act as reducing as well as stabilizing agents.

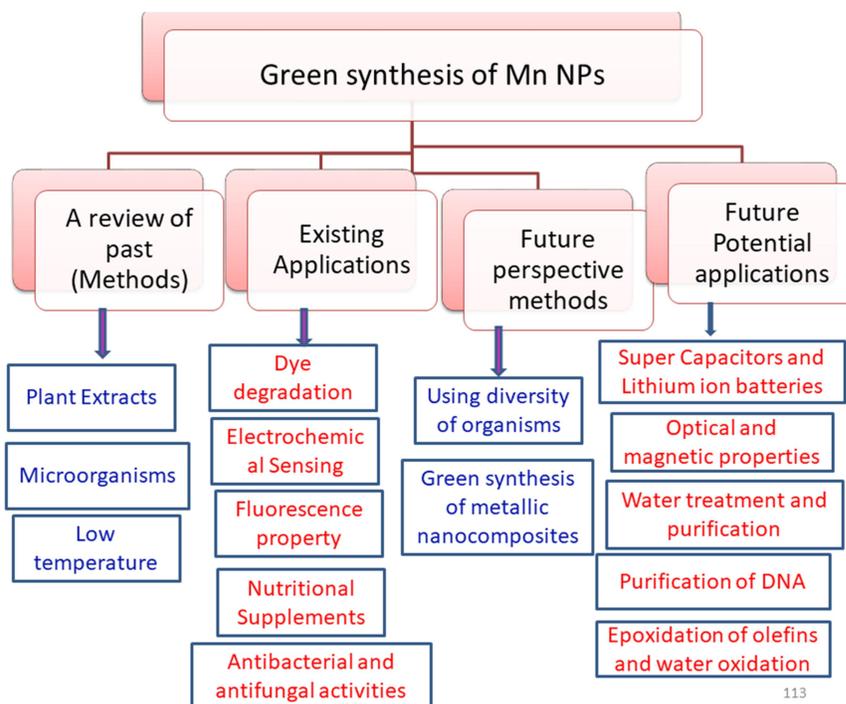


Figure 1: Biogenic synthesis of Mn NPs and its Potential applications

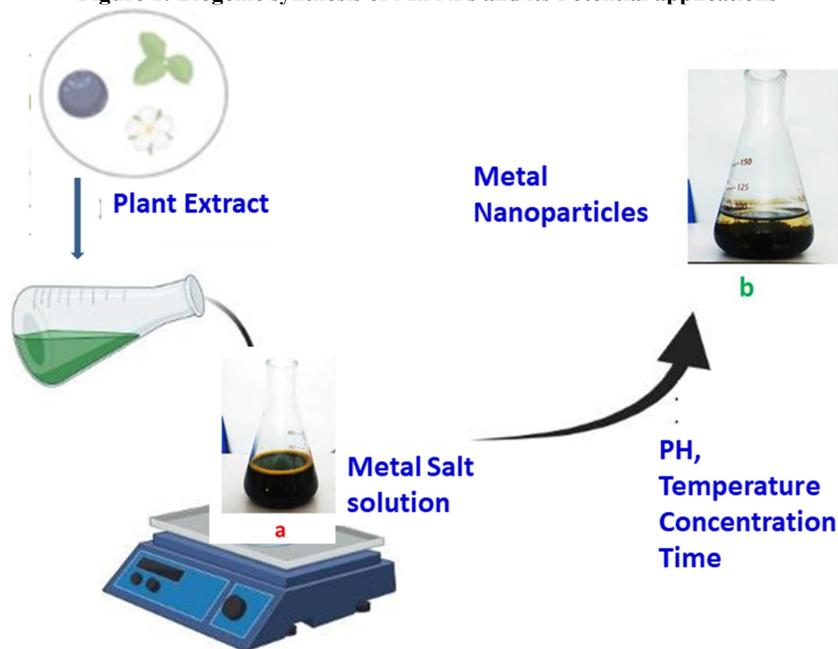


Figure 2: One step process for plant extract mediated green synthesis of MNP

RECENT WORK

Jayandran *et al.* introduced synthesis of Manganese nanoparticles by reducing the metal ions using natural lemon extract and selected turmeric plant was used to synthesize bioactive curcumin and this curcumin extract was used as a stabilizer for manganese nanoparticles. This process was completely undertaken through green synthesis route. The synthesized Mn nanoparticles morphology and size were investigated by SEM and TEM analysis. The morphology study has been revealed the particle size was 50 nm and with spherical and eclipsed morphology. The antimicrobial activity was also investigated against two gram positive bacteria and two gram negative bacteria and four fungus [14].

Kumar *et al.* introduced synthesis MnO NPs of different sizes using *Syzygium aromaticum* extract as reducing and stabilizing agents. MnO NPs fabricated using this green chemistry approach has been effectively used for the electrochemical detection of p-nitrophenol. The MnO NPs/BCA/gold electrode has shown good electro catalytic activity to p-nitrophenol. Hence, the as-prepared electrochemical sensor has good sensitivity and low limit of detection for p-nitrophenol. The interference and selectivity studies revealed that the present system has

good selectivity for PNP in presence of interfering moieties. So this MnO NPs based electrochemical sensor is a robust and sensitive technique for PNP detection. Further, the MnO NPs can also be very useful for sensing other harmful chemicals and in various in vivo biological applications [15].

Prasad *et al.* described a facile, convenient, and green pathway for MnO₂ nanoparticles (MnNPs) synthesis using manganese acetate salt as a precursor and methanolic extract of *Phyllanthus amarus* as a reducing agent. Curcumin extracted from turmeric was used as a stabilizing agent [16].

Hoseinpour *et al.* studied the synthesis of MnO₂ NPs using *Y. gloriosa* leaf extract and Curcumin as a reducing and stabilising agent, respectively. The MnO₂ NPs synthesized by the green method demonstrated the anti-oxidation ability of *Y. gloriosa*. UV-vis, FTIR, XRD, and FESEM studies have shown the presence of the MnO₂ NPs. The XRD study confirms the presence of MnO₂ NPs with ~80 nm size. The photocatalytic activities for dye degradation of the MnO₂ NPs were evaluated using Acid Orange as an organic contaminant and showed promising results for degradation of the organic dye [17].

Study described by Ahmed *et al.* was aimed at synthesizing manganese oxide nanoparticle from *Cassia tora* aqueous leaf extract in order to investigate the toxicological effect of the biologically synthesized manganese oxide nanoparticles (MnO₂ NPs). This study reported that the Manganese oxide nanoparticle biosynthesized from the aqueous leaf extract of *Cassia tora* possess slight toxicity on the liver and kidney and have somehow harmful effects [18].

In another study Asaikkutti *et al.*, Mn₃O₄ NPs (10–34 nm) were synthesized using *Ananas comosus* (*L.*) peel extract at room temperature. HR-SEM images displayed Mn₃O₄, with an average size of 40–50 nm and spherical in shape. The Zeta potential showed the negative surface charge for Mn₃O₄ NPs [19].

Souri *et al.* reported the optimization of green synthesis of MnO NPs with *Dittrichia graveolens* (*L.*) extract via RSM. The central composite design was employed to measure the effect of the extract, metal ratio, time, and pH on the preparation of MnO NPs. The MnO NPs average size at optimal condition was measured about 38 nm [20].

Li *et al.* recently described manganese dioxide NPs (VBLE-MnO₂ NPs) were synthesized using the leaves extract of *V.*

betonicifolia in which the plant's secondary metabolites functions as both reducing and capping agents. The synthesized VBLE-MnO₂ NPs were investigated for different biological activities (antioxidant, cytotoxicity, antibacterial, antifungal, and biofilm inhibition). The results were demonstrated that the synthesized VBLE-MnO₂ NPs presented excellent antibacterial, antifungal, and biofilm inhibition performance against all the tested microbial species compared to plant leaves extract and commercially purchased chemically synthesized manganese dioxide NPs (CH-MnO₂ NPs). The enhanced antioxidant, cytobiocompatibility, antibacterial, antifungal, biofilm inhibition, and cytotoxic efficacy of VBLE-MnO₂ NPs as compared to CH-MnO₂ NPs might be attributed to the synergistic effect of the nanoparticle's physical properties and the adsorbed biologically active phytochemicals from the leaves extract of *V. betonicifolia* on their surface. The work offers a unique environmentally sustainable technique for the manufacture of nanomaterials bestowed with enhanced and/or additional therapeutic properties obtained from their herbal sources [21].

Furthermore, synthesis, applications and challenges with respect to conventional

methods, such as hydrothermal, sol–gel, oxidation–reduction used for the generation of MnO₂ NPs are described in review study of Parajuli *et al.* Likewise, morphological characterization by various spectroscopic techniques also outlined [22].

From the different plant mediated methods for synthesis of Mn nanoparticles as described in present study, unit operation and machinery employed are as shown in **Table 1**.

Table 1: Unit operations for plant extract mediated green synthesis of Mn NP.

UNIT OPERATION	MACHINERY EMPLOYED
Plant material and processing	Milling- Hammer mill, roller flake, seed grater etc. Phytochemical screening- LCMS-MS, Super Critical Fluid Chromatography etc.
Plant extraction	Principle equipment- distillation, soxhalation in Hydro distillation unit Buchi Extraction system B-811, Buchi Rota vapors, Phase exchange-liquid liquid extraction facility etc.
Metal salt solution and Green Synthesis Product collection	Equipment-stirring tanks , reactors etc. Common equipment- centrifugation, lyophilizing.

CONCLUSION

This review was written to gain insight into the biogenic synthesis and characterization of Mn NPs, as well as their possible applications from recent study. The plant extracts are an excellent source of phytoconstituents. Various functional groups found in plants are involved in the reduction, synthesis, and stabilization of Mn NPs. Plant extract mediated green synthesis, as in understood from the review literature has gained importance and has also shown to be promising in terms of the pharmacological activity, antioxidant, antimicrobial, and anticancer effects.. The various process parameters determine Mn NP formation and clearly indicate that plant extract mediated green synthesis has tremendous potential for

researcher in the role to streamline and validate the process. The yield of Mn NP from plant extract mediated green synthesis has not been highlighted much, which calls for attention. Literature also reveals that commercialization of plant extract mediated green synthesis of Mn NP is quite feasible.

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