


Chapter 4

Green Synthesis of Iron Nanoparticles: Methods, Characterization, and Applications

Aditya Shrivastav


 <https://orcid.org/0009-0000-8461-8171>

Ajeenkya D.Y. Patil University, India

Sunil Sankathala

Ajeenkya D.Y. Patil University, India

Susanta Das

 <https://orcid.org/0000-0002-9314-3988>

Ajeenkya D.Y. Patil University, India

ABSTRACT

The rapid advancements in nanotechnology have significantly transformed various industries, with iron-based nanoparticles emerging as a key material due to their unique properties and diverse applications. Green synthesis methods provide an eco-friendly and sustainable alternative to conventional chemical/physical synthesis, utilizing biological agents such as plant extracts, algae, & micro-organisms. These methods rely on phytochemicals as reducing and stabilizing agents, ensuring minimal environmental impact while enabling precise tailoring of nanoparticle properties. Biogenic FeNPs demonstrate immense potential across multiple domains: targeted drug delivery, wastewater treatment and pollutant removal, in agriculture as green alternatives to chemical pesticides, and in catalysis for energy-efficient chemical reactions. This chapter highlights the potential of green-synthesized iron

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nanoparticles and emphasizes the need for continued research to advance sustainable practices, paving the way for groundbreaking applications that benefit both industry and the environment.

1. INTRODUCTION

The fast advancements in nanotechnology have brought iron nanoparticles (FeNPs) to the front, thanks to their unique features & benefit across environmental and medical research. Owing to their unique properties, ability to be manipulated magnetically and adaptable surface chemistry, applications of FeNPs in catalysis, clean-up of pollutants, medical care, drug delivery and magnetic resonance imaging are possible (Alphandéry, 2020; Shabbir et al., 2023). Still, traditional methods to make FeNPs include physical and chemical processes and these approaches can be harmful to both people and the environment. Consequently, they encourage researchers to come up with more sustainable and friendly alternatives (Batoool et al., 2021; Nahari et al., 2022).

Many researchers are interested in iron nanoparticles because they are both highly reactive and their magnetic properties can be adjusted. FeNPs also contribute in the environmental science because of their ability of cleaning contaminated water & soil by eliminating heavy metals, chlorinated organic compounds & synthetic dyes. Pollutants interact with their surfaces easily, leading to quick degradation and magnets enable easy recovery and collection following treatment. FeNPs are commonly used in targeted drug delivery, cancer therapy using hyperthermia, enhancing MRI images and fighting different microorganisms. Since they are biocompatible and can be modified, they help produce new and sophisticated medicines and devices (Alphandéry, 2020; Shabbir et al., 2023).

Although they may be modified, chemicals can still only be reduced, decomposed by heat or ground down with limitations. In general, these strategies require reductants like sodium borohydride and hydrazine, various solvents and a lot of energy, leading to risk for the environment and increased contaminants. After synthesis by traditional ways, nanoparticles often need more treatment to become more stable and fit for use in biology and this takes more time and effort. Using specific methods may cause the FeNPs to have incorrect structures and sizes, making them not suitable for practical uses in environments and medicine (Batoool et al., 2021; Nahari et al., 2022). As concern about the environment and safety in traditional synthesis persists, green synthesis provides a safer and more sustainable way to make FeNPs. Since it underlines the significance of using environmentally safe solvents, renewable raw materials and more efficient processes, this practise supports the ideas of green chemistry (Batoool et al., 2021; Ashrafi-Saiedlou et al., 2025; Nahari et al.,

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