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Green Synthesis and Characterization of Iron-Based Nanoparticles for Environmental Applications

Jagannath S. Godse[1,2], Bhawna P. Pingle[1], Umesh Gadodia[1], Santosh B. Gaikwad[3], Sanjay B. Ubale[1], Rajendra P. Pawar[4*]

[1]Department of Engineering Science, Hi-Tech Institute of Technology, MIDC Waluj, Aurangabad – 431 136, Maharashtra, India

[2]Department of Chemistry, Deogiri College, Aurangabad - 431 005, Maharashtra, India

[3]Department of Chemistry, L P G Arts and Science College, Shirpur (Jain), Washim-444 504, Maharashtra, India

[4]Department of Chemistry, Shivchhatrapati College, Aurangabad – 431 005, Maharashtra, India

ABSTRACT

Researchers have been able to create and synthesise nanosized materials with novel physicochemical properties in recent years, opening a wide range of potential uses in the biomedical area. Since nanotechnology is becoming increasingly applicable and influential in many other fields, there has been a significant increase in the usage of efficient and environmentally friendly synthetic techniques or procedures for the synthesis of iron-based nanomaterials. we examine the existing research on how to responsibly manufacture nanoparticles made of iron. When compared to more conventional approaches, plant-mediated synthesis stands out as an innovative and environmentally friendly way to create nanomaterials. This is because of the eco-friendliness and ease of its procedures. Compared to traditional techniques of synthesis, the produced nanoparticle is easier to make, more stable, and effective in a variety of application in different areas. This investigation, which focuses on the iron-based nanoparticles, provides information on the numerous sources employed thus far and the process by which the materials were developed for use in environmental applications.

Keyword: iron oxide nanoparticle; biomedical application; environmental; green methods.

I. INTRODUCTION

Nanotechnology is a rapidly expanding interdisciplinary field that will have far-reaching consequences across industries like medicine, ecology, and food production. Nanotechnology has been the focus of many studies aimed at reducing or eliminating pollution in aquaculture. Due to their extremely small size in nm and high surface-to-volume ratio, the physical and chemical properties of nanoparticles differ from those of other substances with the same chemical makeup. They are also used to get rid of pollutants, contaminants, and heavy metals [1-2]. Their nanoscale dimensions make them applicable in numerous fields, including mining, mass production, healthcare, chemistry, ecology, power generation, and agriculture. While "bottom-up" procedures employ chemical reduction, electrochemical approaches, and no breakdown, "bottom-to-top" strategies involve the self-assembly of atoms to new nuclei, which grow into nanosized particles. Physical and chemical nanoparticle synthesis methods have significant limitations, including poor surface formation, limited production rate, high production cost, high energy needs, and the use of hazardous reducing agents. Enzymes and other biologically active molecules are used as reducing and capping agents in biological synthesis, which also reduces energy consumption and allows for large-scale production. Synthesis relied on the usage of microorganisms and plant materials. The requirement to keep cell cultures and work in an aseptic atmosphere are major hurdles for microbe-mediated synthesis[3-4]. Plants are the best mediators of synthesis, therefore. Remediating wastewater contaminated with heavy metal ions is best accomplished through adsorption using a variety of adsorbents. The magnetic property, catalytic activity for removing pollutants from water bodies, low cost, high surface area, high functionalization, high adsorption capacity for several contaminants in water and wastewater treatment, antimicrobial and antioxidant activities, and abundance make iron-based nanoparticles important among synthesized nanoparticles [5-6].

According to their characterization results, the iron-based nanoparticles comprised iron oxide and had spherical cores ranging in size from 30 to 80 nm [7]. The strong reactivity of these iron-based nanoparticles was further demonstrated by their capacity to extract transition metal solution. This approach is promising for remediating transition metal polluted water and creating green nanoparticles. Toxic organic pollution removal is just one example of the many potential scientific and technological uses for ecologically friendly iron oxide nanoparticle manufacturing, which the author believes has the potential to be an efficient, cost-effective, and practical technology in the future. Nanoparticles were typically round, square, or octagonal in size. This method has a low cost, can be easily replicated, and is good for the planet. Recent research has uncovered methods to synthesize iron-based nanoparticles for environmentally beneficial treatments and applications, going beyond traditional and obsolete technologies in the process. This involves limiting the use of damaging and depleting material inputs, increasing the efficiency of time, space, and energy, and more.

II. GREEN SYNTHESIS METHODOLOGY OF IRON OXIDE NANOPARTICLES

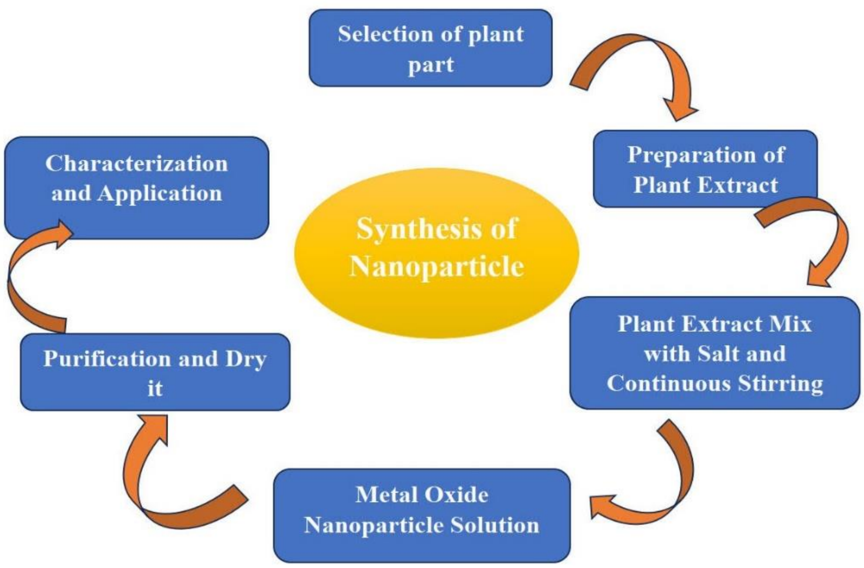

Fig.1. Synthesis of Iron Oxide nanoparticles

Figure 1 depicts the most prevalent methods for synthesis of iron oxide nanoparticle, efficient extraction of the bioactive components of plant materials, such as leaves, stems, or roots, is necessary to produce iron-based nanoparticles [8]. Polyphenols, saponins, organic acids, vitamins, polysaccharides, and other organic solvents like methanol and acetone are examples of these substances. They serve as capping and reducing agents in a reaction with a precursor, often an ferric chloride solution. Zero-valent ion nanoparticles are produced when Fe^{3+} is transformed to FeO. For instance, zero-valent iron was created using the polyphenols in dried green tea extract. Green tea leaves' polyphenols were extracted using a microwave to create nanoparticles with a size range of 10 to 30 nm. Bioactive substances called polyphenols are widely found in plant leaves. Ethanol was used to extract the green tea powder, which was subsequently cooled and filtered. Zero-valent iron nanoparticles were created by mixing an iron (III) chloride solution with a polyphenol-rich plant extract. An overview of plant-based methods for creating nanoparticles can be found in the following [9]. Since biomolecule, bacterial, and fungal nanoparticle synthesis need labor-intensive, high-maintenance cultures and continual sterile conditions, plant nanoparticle manufacture is preferred [8, 10].

III.CHARACTERIZATION OF IRON OXIDE NANOPARTICLES

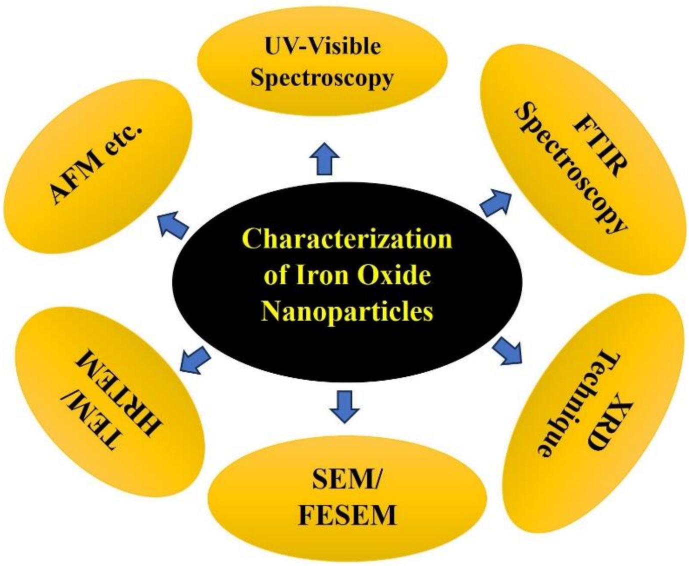

Fig.2.Characterization of Iron Oxide Nanoparticles

A variety of methodologies can be used to better understand the magnetic characteristics of iron oxide nanoparticles and examine their physiochemical properties [11]. This category includes spectroscopic, microscopic, and magneto metric approaches. Infrared spectroscopy (IR), X-ray photoelectron spectroscopy (XPS), Fourier transform infrared spectroscopy (FTIR), Electrophoresis, Zeta potential measurement, Thermal gravimetric analysis (TGA), Ultraviolet - visible spectroscopy (UV-VIS), and many other techniques are available [12].

Figure 2 depicts the most prevalent methods for analyzing nano-sized iron oxide particles. A wide range of spectroscopic approaches are used to examine the nano-sized iron oxide particles. The fundamental approach for probing any nanomaterial is XRD. X-ray diffraction was used to investigate the crystalline structure and size of nanoparticles. In order to determine the sizes of the nanoparticles, Scher-rer's equation [13-14] is applied to the main peaks of the XRD pattern. The huge peaks make predicting the size of nanocrystalline nanoparticles problematic. TEM/HRTEM can measure the size and shape of nanoparticles in suspension. Scanning electron microscopy (SEM)/field emission scanning electron microscopy (FESEM) and atomic force microscopy (AFM) are used to investigate iron oxide nanoparticles. Based on the images we took; we can approximate the size (in terms of diameter). TEM investigation can provide an estimate of the electron phase shift, crystallinity, nanoparticle aggregation state, and lattice spacing. The AFM instrument is useful for determining surface roughness, step height, and the location of scattered particles. Structures and functional groups are identified using FTIR spectroscopy. Light with wave numbers ranging from 4000 to 660 cm^{-1} is absorbed by nanoparticle molecules. Thermogravimetry can be used to learn about the thermal stability of iron oxide nanoparticles. The chemical kinetics, molecular transport, and other effects of nanoparticle concentration are studied using visible and UV-light-based fluorescence correlation spectroscopy[15-16].

IV. APPLICATION OF IRON OXIDE NANOPARTICLES

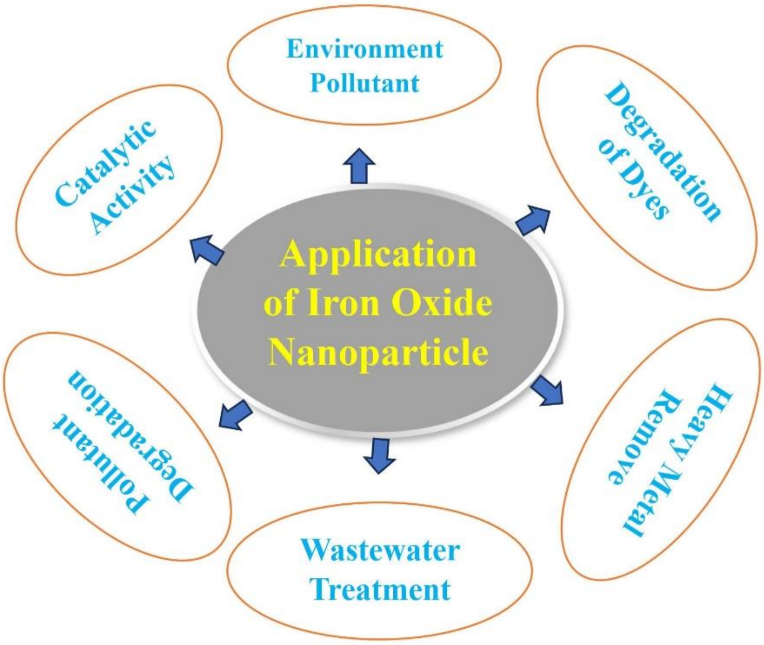

Fig.3. Application of Iron Oxide Nanoparticles

To synthesize nanoparticles in a way that is both effective and benign to the environment, it is recommended that green chemistry principles be adhered to. This means that the green synthesis process should use minimal amounts of heat and solvents to extract the active bio-component from low-energy sources such plants, microbes, biopolymers, and waste materials and many more application show in figure 3. Biomolecules, especially polyphenols, which are derived from plants and employed as reducing, capping, and stabilizing agents, have been dissolved in water in several investigations. Leaves, branches, roots, flowers, fruits, fruit peels, seeds, gums, and even rubbish have all been mined for these bioactive polyphenols[17-18]. Methyl orange, malachite green, and orange dye are only a few examples of the toxic compounds released into the environment during production. Among the heavy elements are arsenic and chromium. Many organic and inorganic substances should not be present in water because of their toxicity and cancer-causing qualities [19]. Recent research has shown that iron nanoparticles can be employed for environmental purification [20]. Iron-based nanoparticles are useful in environmental cleanup, especially for in situ methods, due to their adsorptive and reductive capabilities. They are cheap, harmless to humans and animals, and efficient at decomposing many different types of organic and inorganic pollutants. In addition, their efficacy can be improved by combining them with other methods, such as chemical oxidation, bioremediation, and chemical oxidant activation [21]. Dyes have an affinity for a surface when applied to it due to the chemical structure they contain. Dyeing refers to the method by which colourants are permanently affixed to textiles and other materials used in the food, garment, and other industries. The iron nanoparticles used to bleach methyl orange and sterilize bacteria were synthesised using chlorophyte comosum leaf extract. Chloropytum comosum leaf extract water dispersion is used to treat the iron salt precursor as a reducing and stabilising agent. Methyl orange was used to test the efficiency of H_2O_2-catalyzed iron nanoparticles at removing dyes and degrading organic pollutants. Degradation of methyl orange is shown to be most effective after few hours [22]. Another study demonstrated that in the presence of an aqueous H_2O_2 solution, iron oxide nanoparticles synthesised using a green process were particularly effective at degrading methyl orange. The results showed that between 5-40 nm in diameter, the great majority of iron oxide nanoparticles are round. Green and sustainable, plant-mediated synthesis of iron oxide nanoparticles has many potential uses. One of these is as a heterogeneous Fenton-like catalyst for the degradation of azo dyes[23-24]. Results from experiments corroborate claims that magnetic graphene oxide laccase nanoparticles improve processing efficiency and provide novel enzyme applications in industry. Iron Oxide Nanoparticles were also synthesized spontaneously using extract from the piper beetle. The Piper beetle's phenolic compounds have been hypothesized to act as capping or reducing agents. The manufactured iron oxide nanoparticles significantly sped up the breakdown of MO and MG dyes [25]. Electron-hole pairs are produced during the photocatalytic degradation of dye due to irradiation, and these react with the surface of the nanoparticle to produce hydroxyl radicals. Toxic pigments can be broken down by these radicals due to their oxidizing capabilities. Nanoparticles act as photocatalysts when exposed to light of any wavelength, including visible and UV light. This exposure triggers a redox process that results in the creation of electron hole pairs via the release of electrons from the conduction band and protons from the valence band. Surface electron-hole interactions in a photo catalyst set off a cascade of redox events. At the same time, OH free radicals are created when H^+ is oxidized by water. The reduction process on the surface of nanoparticles as a photocatalyst begins with a reaction between electrons in the conduction band and oxygen, yielding intermediates such superoxide radical, per hydroxyl radical, H_2O2, and finally •OH. Harmful pigments can be broken down with the help of this radical [26-27].

V. CONCLUSION

The rapidly developing field of "green synthesis" studies effective, eco-friendly ways to make nanoparticles. Using green reagents and more environmentally friendly manufacturing techniques, green synthesis aims to have less of an impact on the environment than standard synthesis methods. We examined the most recent studies on sustainable methods of creating nanoparticles for wastewater treatment in this post. Several instances of environmentally benign nanoparticles have been highlighted. One of the biggest challenges in the synthesis of nanoparticles for environmental cleanup is controlling particle size and morphology. It was demonstrated that variables related to green synthesis, like pH, temperature, and reaction time, might change these characteristics. It was shown by going over their efficacy and pollutant removal techniques that green nanoparticles might help with dye degradation and water pollution removal. Degradation processes, heavy metal adsorption, and pollutant degradation were all investigated in detail. Future research avenues that are worth pursuing include large-scale assembly, the possible effects of greener nanoparticles on plants, improvements in the shape of green nanoparticles, and the regeneration of iron-based nanomaterials following adsorption.

VI. ACKNOWLEDGMENTS

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VII. CONFLICTS OF INTEREST

The authors declare no conflict of interest.

VIII. REFERENCES

[1]. Cai, C.; Zhao, M.; Yu, Z.; Rong, H.; Zhang, C., Utilization of nanomaterials for in-situ remediation of heavy metal (loid) contaminated sediments: A review. Science of the Total Environment 2019, 662, 205-217.

[2]. Palani, G.; Arputhalatha, A.; Kannan, K.; Lakkaboyana, S. K.; Hanafiah, M. M.; Kumar, V.; Marella, R. K., Current trends in the application of nanomaterials for the removal of pollutants from industrial wastewater treatment—a review. Molecules 2021, 26 (9), 2799.

[3]. Kolahalam, L. A.; Viswanath, I. K.; Diwakar, B. S.; Govindh, B.; Reddy, V.; Murthy, Y., Review on nanomaterials: Synthesis and applications. Materials Today: Proceedings 2019, 18, 2182-2190.

[4]. Khan, F. A., Synthesis of nanomaterials: methods & technology. Applications of nanomaterials in human health 2020, 15-21.

[5]. Leonel, A. G.; Mansur, A. A.; Mansur, H. S., Advanced functional nanostructures based on magnetic iron oxide nanomaterials for water remediation: a review. Water research 2021, 190, 116693.

[6]. Pasinszki, T.; Krebsz, M., Synthesis and application of zero-valent iron nanoparticles in water treatment, environmental remediation, catalysis, and their biological effects. Nanomaterials 2020, 10 (5), 917.

[7]. Sangaiya, P.; Jayaprakash, R., A review on iron oxide nanoparticles and their biomedical applications. Journal of Superconductivity and Novel Magnetism 2018, 31, 3397-3413.

[8]. Yadwade, R.; Kirtiwar, S.; Ankamwar, B., A review on green synthesis and applications of iron oxide nanoparticles. Journal of Nanoscience and Nanotechnology 2021, 21 (12), 5812-5834.

[9]. Jacinto, M.; Silva, V.; Valladão, D.; Souto, R., Biosynthesis of magnetic iron oxide nanoparticles: a review. Biotechnology Letters 2021, 43, 1-12.

[10]. Akintelu, S. A.; Oyebamiji, A. K.; Olugbeko, S. C.; Folorunso, A. S., Green synthesis of iron oxide nanoparticles for biomedical application and environmental remediation: a review. Eclética Química 2021, 46 (4), 17-37.

[11]. Ali, A.; Zafar, H.; Zia, M.; ul Haq, I.; Phull, A. R.; Ali, J. S.; Hussain, A., Synthesis, characterization, applications, and challenges of iron oxide nanoparticles. Nanotechnology, science and applications 2016, 49-67.

[12]. Ansari, S. A. M. K.; Ficiarà, E.; Ruffinatti, F. A.; Stura, I.; Argenziano, M.; Abollino, O.; Cavalli, R.; Guiot, C.; D'Agata, F., Magnetic iron oxide nanoparticles: synthesis, characterization and functionalization for biomedical applications in the central nervous system. Materials 2019, 12 (3), 465.

[13]. Godse, J. S.; Gaikwad, S. B.; Suryawanshi, R.; Ubale, S. B.; Pawar, R. P., An Overview of Green Synthesis & Biomedical Applications of Zinc Oxide (ZnO) Nanoparticles.

[14]. Bodaghifard, M. A.; Hamidinasab, M.; Ahadi, N., Recent advances in the preparation and application of organic–inorganic hybrid magnetic nanocatalysts on multicomponent reactions. Current Organic Chemistry 2018, 22 (3), 234-267.

[15]. Samrot, A. V.; Sahithya, C. S.; Selvarani, J.; Purayil, S. K.; Ponnaiah, P., A review on synthesis, characterization and potential biological applications of superparamagnetic iron oxide nanoparticles. Current Research in Green and Sustainable Chemistry 2021, 4, 100042.

[16]. Chekli, L.; Bayatsarmadi, B.; Sekine, R.; Sarkar, B.; Shen, A. M.; Scheckel, K.; Skinner, W.; Naidu, R.; Shon, H.; Lombi, E., Analytical characterisation of nanoscale zero-valent iron: A methodological review. Analytica chimica acta 2016, 903, 13-35.

[17]. Shafey, A. M. E., Green synthesis of metal and metal oxide nanoparticles from plant leaf extracts and their applications: A review. Green Processing and Synthesis 2020, 9 (1), 304-339.

[18]. Annu, A. A.; Ahmed, S., Green synthesis of metal, metal oxide nanoparticles, and their various applications. Handbook of Ecomaterials 2018, 2018, 1-45.

[19]. Madhav, S.; Ahamad, A.; Singh, A. K.; Kushawaha, J.; Chauhan, J. S.; Sharma, S.; Singh, P., Water pollutants: sources and impact on the environment and human health. Sensors in water pollutants monitoring: Role of material 2020, 43-62.

[20]. Saif, S.; Tahir, A.; Chen, Y., Green synthesis of iron nanoparticles and their environmental applications and implications. Nanomaterials 2016, 6 (11), 209.

[21]. Li, X.; Liu, L., Recent advances in nanoscale zero-valent iron/oxidant system as a treatment for contaminated water and soil. Journal of Environmental Chemical Engineering 2021, 9 (5), 106276.

[22]. Radini, I. A.; Hasan, N.; Malik, M. A.; Khan, Z., Biosynthesis of iron nanoparticles using Trigonella foenum-graecum seed extract for photocatalytic methyl orange dye degradation and antibacterial applications. Journal of Photochemistry and Photobiology B: Biology 2018, 183, 154-163.

[23]. Yuan, M.; Fu, X.; Yu, J.; Xu, Y.; Huang, J.; Li, Q.; Sun, D., Green synthesized iron nanoparticles as highly efficient fenton-like catalyst for degradation of dyes. Chemosphere 2020, 261, 127618.

[24]. Hafaiedh, N. B.; Fourcade, F.; Bellakhal, N.; Amrane, A., Iron oxide nanoparticles as heterogeneous electro-Fenton catalysts for the removal of AR18 azo dye. Environmental Technology 2018.

[25]. Shalaby, S. M.; Madkour, F. F.; El-Kassas, H. Y.; Mohamed, A. A.; Elgarahy, A. M., Green synthesis of recyclable iron oxide nanoparticles using Spirulina platensis microalgae for adsorptive removal of cationic and anionic dyes. Environmental Science and Pollution Research 2021, 28, 65549-65572.

[26]. Chaudhary, R. G.; Bhusari, G. S.; Tiple, A. D.; Rai, A. R.; Somkuvar, S. R.; Potbhare, A. K.; Lambat, T. L.; Ingle, P. P.; Abdala, A. A., Metal/metal oxide nanoparticles: toxicity, applications, and future prospects. Current Pharmaceutical Design 2019, 25 (37), 4013-4029.

[27]. Lu, K.; Shen, D.; Liu, X.; Dong, S.; Jing, X.; Wu, W.; Tong, Y.; Gao, S.; Mao, L., Uptake of iron oxide nanoparticles inhibits the photosynthesis of the wheat after foliar exposure. Chemosphere 2020, 259, 127445.